The
ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XVII No. 11 NOVEMBER, 1956

STC

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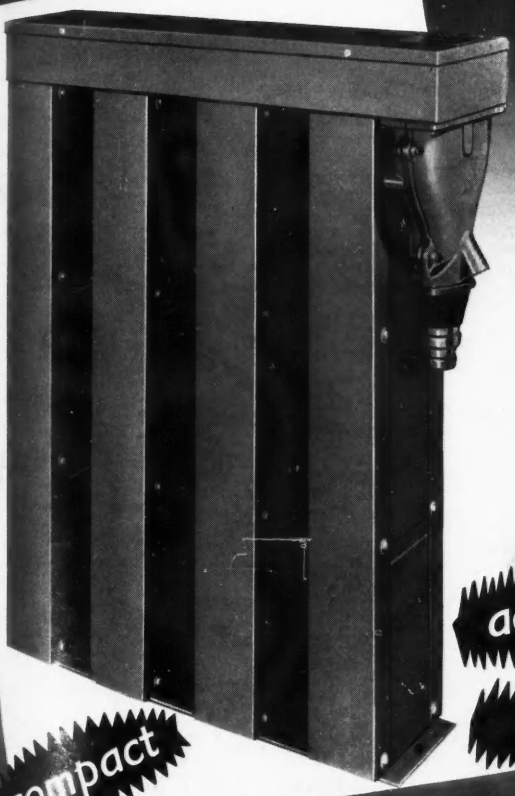

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CONTENTS

	Page
The Blue Pages	455
Materials in Automobiles of the Future	459
The Testing of High-Voltage Circuit-Breakers	461
Gallium	465
Principles and Characteristics of Solar Furnaces	466
Analysis of the Temperature Field in a Gas-Turbine Rotor, using a Hydraulic Integrator	469
The Control of D.C. Multi-Motor Drives for Textile Machines by Magnetic Amplifiers	472
The Principle of "Convergence-Divergence" in Mixing and Other Applications	475
Pneumatic Computing Elements for Automatic Controls	480
British Industrial Developments	483
Classified Abstracts	487
New Materials, Processes, and Equipment	489
News of the Month	493

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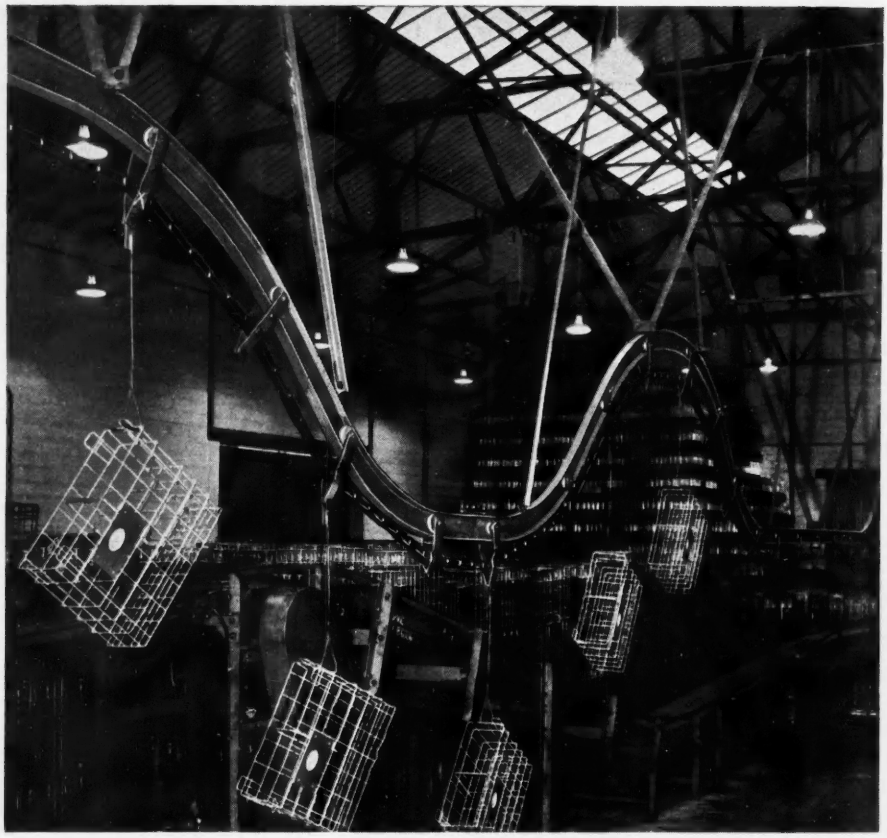

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *PRODUCTION OF LOW-DENSITY FERROUS PARTS*

A proposal has been made to manufacture ferrous parts from pulverized iron oxide in such a way as to obtain a product with a controlled density less than that of the solid metal. Moreover, abrasive materials, such as diamonds, silicon carbide, and alumina, can be mixed with the iron oxide. As an example, cutting wheels may be fabricated by mixing diamonds, suitably coated with a protective coating such as copper, with the iron oxide particles, producing a disc of steel of required density and strength to perform as a cutting wheel. Another proposed application is the production of high-temperature turbine blades for jet engines. As is well known, such blades may be produced by providing a blade tip composed mainly of alumina to operate in the high-temperature zone. The percentage of alumina in the steel can be reduced away from the tip until the body of the blade is composed mainly of steel. By packing the iron oxide and alumina before reduction of the oxide, the steel will carry the same distribution of alumina in the final article. A variation in density may also be produced by predetermined distribution of the oxide particles according to their size. The process involves pressing of the iron oxide powder and subsequent reduction at high temperature. It is stated that the process can be extended to producing alloy-steel parts. In the case of metal oxides which reduce with about the same ease as iron oxide and at the same temperature, oxides of these metals may be mixed with the iron oxide before shaping the part by pressing. During the process the additional oxides will be reduced to metal which will alloy with the iron. Among others, suitable oxides are those of vanadium and cobalt.

● *TRANSISTORIZED ELECTRONIC FUEL-INJECTION SYSTEM*

A novel, completely transistorized electronic fuel-injection system for use on passenger-car engines has been developed. The system consists of a transistorized electronic modulator, a fuel-injection distributing commutator, fuel-injection breaker points, and fuel-injection nozzles especially designed to minimize dirt problems. The timing, sensing, and actuating elements include an electronic pressure-sensing device, located on the throttle body, together with an electronic switch to sense and signal the need for proper fuel mixture, either for acceleration or idling. Another feature on the throttle body is an automatic cut-off switch. A thermistor is located in the water jacket to sense and pass along temperature data to the electronic modulator, this feature being stated to provide optimum performance in starting and warming up. The device shoots jets of fuel, electronically timed, into the intake ports of the cylinders of the engine. The fuel is metered by the intake-manifold pressure, controlled automatically by a senser on the throttle unit. Another feature of the new automatic unit is its distributor-breaker system, which can be installed, it is stated, on any conventional distributor, and which will add only about one inch to the overall height of the distributor. This system consists of two parts, the commutator and the breaker points, the "brain" of the system being the electronic modulator, which receives a timed signal from the distributor-breaker. The modulator coordinates this signal with information from the devices which electronically sense engine operating conditions, and continuously sends the correct action signal to injectors located at each cylinder intake port. Optional features of the system include a device to compensate for ambient temperature variation, and automatic compensation for changes in altitude.

● *PROCESS FOR IMPROVING THE SURFACE OF PLASTIC SHEET*

Processes for the production of films and other sheet material from organic plastics employ such methods as extruding or rolling a heated thermoplastic material or casting solutions of the material onto rolls or belts. A recent patent specification points out that these processes do not produce a sheet material of uniform appearance, and certain methods have therefore been evolved to improve appearance by heat and pressure treatment of the sheet. According to the inventors, a more effective process for improving surface appearance consists of subjecting the sheet to pressure and heat by immersing it in a bath of molten metal. In this process a continuous sheet of thermoplastic material is drawn continuously under tension around a number of rolls immersed in a bath of molten metal, maintained at a temperature sufficiently high to soften the material. Thermoplastic materials which can be treated in this way include cellulose acetate, cellulose butyrate, ethyl cellulose, polyvinyl

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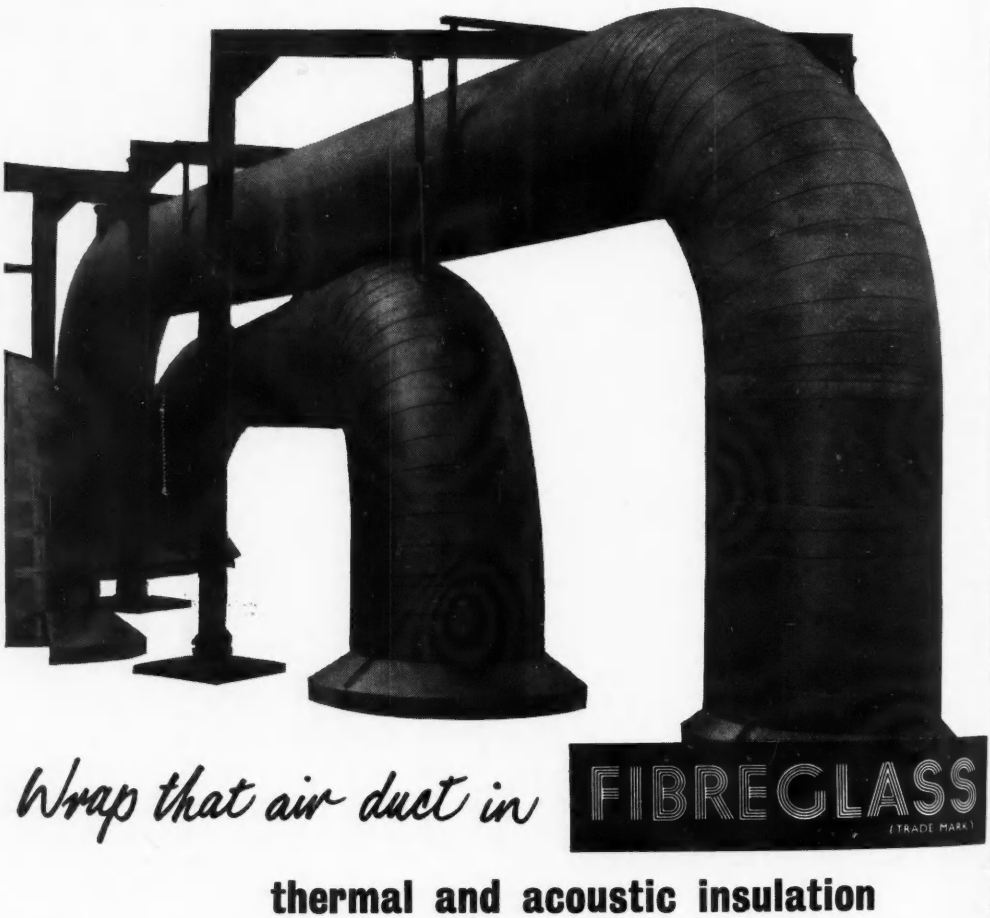

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chloride, vinyl acetate, polystyrene, and polyethylene. The molten metal used in the process may be any of the heavy metals, including alloys, with melting points below the melting point of the thermoplastic sheet material. Thus, suitable metals include mercury, lead, plumber's solder, tin, white metal, bismuth amalgam, and a eutectic alloy of tin, lead, and cadmium. It is particularly desirable to employ a metal which has a high surface tension in the molten state, e.g., mercury, in order to ensure that the metal will have little or no tendency to adhere to the sheet material.

● *ELECTRON STORAGE TUBE FOR IMPROVED RADAR OPERATION*

An electron storage tube has been developed which is claimed to improve radar operation. With this tube a visual image on the radar screen is produced with no dynamic image. The tube is characterized by the ability of its storage surface to integrate the rapidly occurring echo pulses from a target on successive scans by a radar system, this integration being accomplished by charging an elemental area of storage surface in steps to a potential which exceeds a critical value. When this value is reached, electrons from a flood gun preserve the charge for any desired length of time, simultaneously enhancing the signal over the accompanying noise. On the other hand, areas of storage not charged to a potential exceeding the critical potential will give indications of only very short persistence on the viewing screen, thus eliminating for the most part random noise and other disturbances. The tube comprises both a writing gun and a flood gun, of which the former directs a high-energy electron beam over a storage screen in a conventional manner. Acting simultaneously with the writing gun, the flood gun produces a broad beam of low-velocity flood electrons which pass through the interstices of the elemental area of the storage grid assembly in proportion to the charge accumulated on it. The flood electrons are accelerated towards the viewing screen, and the combined effect of the flood electrons impinging on the screen is to produce a representative image of the charge pattern on the storage surface, which is especially designed to be charged with extreme rapidity by the writing beam.

● *LOW-TEMPERATURE STORAGE OF FREE RADICALS*

A technique for capturing and sorting large numbers of highly reactive molecular fragments at temperatures near absolute zero has been developed, in which unstable atoms and free radicals, known to exist but momentarily in flames and hot gases, are produced in an electric discharge, frozen into immobility, and trapped in solid form. Because these atoms are frozen in an excited state, they can be conveniently studied by optical spectroscopy. In this method gases, containing molecules of nitrogen, hydrogen, oxygen, or water, are first passed through a high-frequency electric discharge and then frozen very suddenly at 4·2°K. The discharge is maintained in a wave-guide resonator by a 2450-megacycle power supply. From the resonator, a glass tube leads the resulting molecular fragments into an evacuated metal vessel containing a cold surface in contact with a liquid-helium bath. To prevent solidification of the discharge products at temperatures above 4·2°K, the gases are carried to the cold surface through a passageway which is kept near room temperature by contact with warm helium gas. When the gases reach the cold surface, they freeze into solid form there. In the experiments carried out so far, solids containing atomic nitrogen and oxygen, and possibly atomic hydrogen and an unstable hydroxy molecule, have been produced. These solids have very unusual properties, emitting a bright glow, blue "flames", and coloured flashes of light. When warmed 20 or 30 degrees, they combine very actively, releasing large quantities of stored energy, principally as heat. Possible fields of application include solid-state physics and basic chemistry. Here, the trapped atoms could be used as powerful probes into the solids containing them.

● *SHOCK-TESTING EQUIPMENT*

It is reported that a new device has been evolved which makes it possible to simulate mechanical shock conditions accurately and reliably. Acceleration values several hundred times as great as gravity can be obtained in times measured in milliseconds. The device has a rated output thrust of 12,000 lb, produced from the release of stored energy of a gas compressed to a pressure of 2000 psi, the sudden release of this energy being accomplished by the principle of over-balancing thrust loads. The apparatus is basically a cylinder separated by means of an orifice plate into two chambers, one of which is open-ended. A piston moving in the open-ended chamber is connected to a piston rod, which constitutes the thrust column reacting against the test specimen, while on the underside of the piston, in line with the orifice-plate opening, is mounted a small sealing ring. When the open-ended chamber is pressurized to some low value, the piston is forced down against the orifice plate, and the sealing ring serves to isolate the underface of the piston from the closed-end chamber, except for the small area inside the sealing ring. To obtain a balanced thrust condition on the piston, the closed-end chamber must be pressurized to an extremely high value, since the pressure in this chamber can act only upon the small area of the piston inside the sealing ring.

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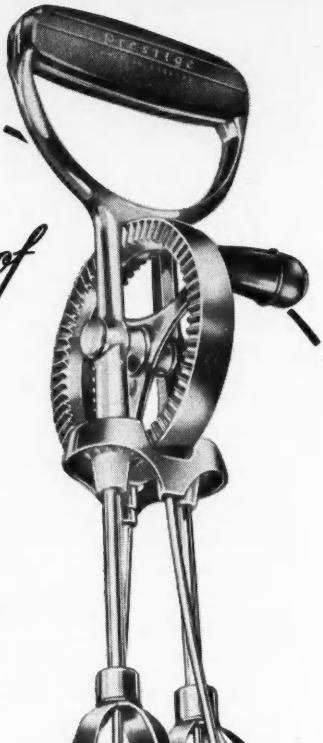

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However, as soon as the pressure in the closed-end chamber is increased above the balanced condition, the piston is forced away from the orifice plate. When this occurs, the sealing ring loses contact with the plate, and the high pressure in the closed-end chamber is instantaneously released, reacting on the entire underface of the piston and producing extremely high acceleration of the piston column and test specimen.

● *TANTALUM CAPACITORS WITH SOLID ELECTROLYTE*

Electrolytic capacitors of the conventional type possess many disadvantages caused by the use of an aqueous electrolyte. Thus, at elevated temperatures electrolytes dry out, unless the capacitors are effectively sealed, while at low temperatures electrolytes congeal or actually freeze, introducing series capacitance and series resistance. Moreover, the use of such electrolytes imposes limitations at high frequencies. A new type of capacitor has, however, been developed in which the aqueous electrolyte is replaced by a solid electrolyte, the capacitor consisting entirely of stable, non-volatile inorganic materials. The anode is made of tantalum, which may be in a variety of forms, such as sintered porous bodies, wire, or foil. It is reported that to date most of the development has been concentrated on capacitors with porous tantalum anodes, because they give the highest capacitance-to-volume ratio. A thin layer of tantalum oxide is formed on the tantalum surface by making the tantalum piece positive with respect to a cathodic member in a suitable electrolytic bath. The thickness of the oxide film will then be proportional to the formation voltage. Capacitance is proportional to the tantalum surface area, and inversely proportional to the oxide thickness. An intimate layer of a semiconductor (manganese dioxide) is deposited over the surface of the tantalum oxide. This manganese dioxide layer is formed by decomposing manganous nitrate introduced in aqueous solution. A carbon layer is added by applying an aqueous dispersion and allowing water to evaporate. The carbon produces intimate electrical contact with the manganese dioxide and constitutes a mechanical buffer between the inner structure and the cathode, relieving strains and allowing for differential thermal expansion.

● *NEW METHOD OF TACK-WELDING OVERLAPPING SHEETS*

A new method and apparatus developed for the tack-welding of overlapping sheets is claimed to be superior to the inert-gas process employing a non-consumable electrode, such as a thoriated tungsten electrode. The new method is stated to dispense with the need for the thorough cleaning of the sheet surfaces in the seam zone, particularly necessary in the case of aluminium and its alloys. Welding is carried out with a consumable electrode, an inert-gas-shielded arc being formed between the electrode and the outer surface of the work. At the exact instant the arc starts, the electrode is automatically fed towards the arc at a very rapid rate, which in the case of a $\frac{1}{16}$-in. welding rod may be 200 in. per minute, while a stream of argon is discharged from the nozzle of the welding gun. The entire welding action is automatically timed, so that a weld with a convex top surface is obtained. In this way any weld crater which would otherwise result is completely filled with metal supplied by the electrode. If the welding-time cycle is even slightly too long, a hole extending through the work will result, while, if the cycle is too short, the bond will be very weak, as the upper surface of the solidified weld exhibits a crater. Exact timing is ensured by means of a relay control which detects the arc at the instant it starts and then interrupts the current supply and the feeding motion of the rod at the proper time. In a modification of the process, the welding action is stopped after the arc has fused through the upper sheet and into, but not through, the lower sheet. A second welding action is carried out after the initial weld deposit has solidified, thus completing the weld by filling the crater.

● *IMPROVING GAS DIFFUSION PROCESSES BY LOW-PRESSURE GLOW DISCHARGES*

A recent invention is concerned with the improvement of metal diffusion processes by applying controlled glow discharges at low pressure to the workpiece. In one application of the principle the glow discharges are applied to the workpiece in pulsating form. A typical example is a method for the nitriding of steel, which is carried out in an atmosphere of ammonia at a pressure of 6 to 15 mm Hg, the duration of the process being 15 hr, using a glow discharge consisting of 550-V pulses having a duration of 0·1 to 0·2 sec, with intervals of 0·4 to 1·4 sec at 350 V. This results in alternate specific loadings of from 2 to 20 W/cm² and forms a nitrided layer of 0·4 to 0·5 mm. The inventor states that formerly nitriding layers of this thickness were obtained only by using a continuous glow-discharge process with a mean voltage between 350 and 550 V, applied for from 40 to 60 hr. It is stated that the temperature maintained in the new method was lower than in the old. Other processes depending upon the diffusion of gases into the surface of the workpiece are claimed to be similarly improved, a noteworthy increase in the rate of diffusion being obtainable. Also, by employing lower temperatures, the results are said to be qualitatively better, since changes in the structure of the material can be avoided. Similar effects can be found, particularly in the

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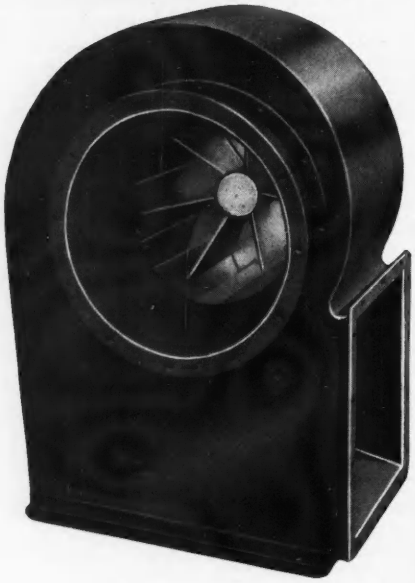

"Airflo" at work

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Bottom, Fume removal from cyanide pots at The Standard Motor Co. Ltd.

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surface diffusion of chromium plated on steel. Moreover, by an acceleration of such diffusion processes, satisfactory results have been obtained in the degassing of metals and the separating out of impurities such as sulphur and phosphorus.

● *"STROBORADIOGRAPHIC" TECHNIQUE FOR X-RAY CINEMATOGRAPHY*

Motion pictures of the inside of an engine while it is running have recently been achieved. The task involves taking X-ray pictures of the internal movements of the engine through its steel housing, and visually stopping with a camera their high-speed motion. It is considered that the new technique, called stroboradiography, could have a significant effect on engineering design. Slow-motion X-ray cinema pictures and still pictures of pistons, cams, and other moving parts have enabled engineers to scrutinize for the first time complete cycles of engine operation for faulty performance or wear. The stroboradiographic equipment employs a high-energy X-ray betatron operating at from 5 to 15 million volts. Unlike conventional X-ray equipment, the betatron furnishes surging radiation impulses (416 per second). The new process involves the taking of thousands of short exposures accurately synchronized with the moving part to be examined. With an exposure time of 10 to 15 microsec, it is possible to radiograph an engine running at several thousand revolutions per minute. A synchronizing disc attached to the revolving part of the engine actuates the betatron and releases the surge of electrons which make the split-second X-ray exposure. The walls of the test specimen, opaque to light, are partially transparent to the high-energy X-ray radiation, thus producing a picture of the internal working parts in their relationship to each other. The difference in the shape and density of the various parts enables the images to assume their proper perspectives in the stroboradiograph.

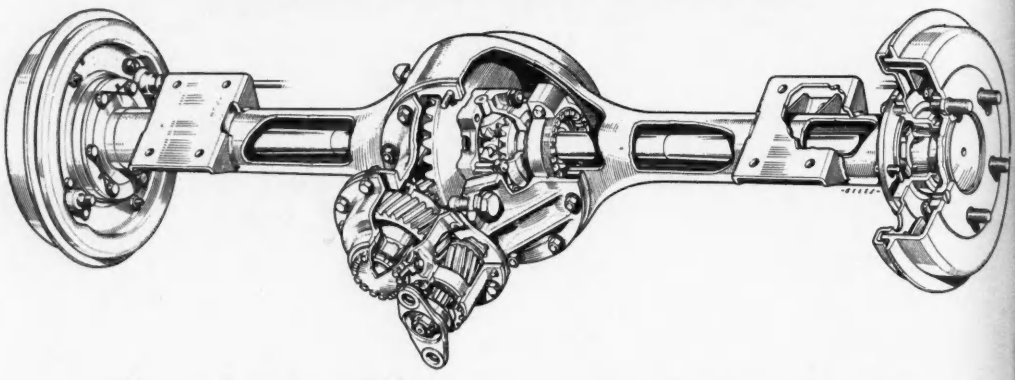
● *NEW ELECTROMAGNETIC SHUTTLE-PROPULSION SYSTEM FOR LOOMS*

Of the various electromagnetic shuttle-propelling systems for looms suggested during the past twenty-five years, the most promising involve the use of a " linear " induction motor, consisting of a stator track carrying a polyphase winding arranged to project a piece of conducting material in a straight line. One of the main disadvantages of such schemes is the necessity of incorporating a switching device, in order to obtain the required two-way motion for weaving. Now, however, a system has been evolved in which it is possible to produce continuous oscillatory motion of an electrically conducting shuttle without the use of any type of switching device. This is achieved by a special design of stator track divided into two halves, the travelling magnetic field produced by each half being directed towards the centre. The " rotor " consists of a squirrel-cage of copper bars in a laminated iron rotor running on rails. The system can be further developed to include the propulsion of non-ferrous conducting rotors, in which case the rotor is propelled horizontally between an upper and a lower stator track and is suspended in space by the magnetic field. The ideal " flying shuttle " is thus obtained, the shuttle making no mechanical contact with the track, which extends right across the loom. The rotor is therefore subjected to forces during its entire flight, and the amplitude and period of the shuttle oscillation can be controlled. An alternative scheme consists of a single-phase double-sided track which provides driving forces on the rotor in the direction of its velocity. Mechanical buffers are incorporated at each end of the track to reverse the velocity, and the impulses received by the buffers can be used to actuate other mechanisms of the loom. The feature of the magnetically suspended shuttle may still be retained during the actual traverse.

● *MANUFACTURE OF HOLLOW TURBINE BLADES*

A recent patent specification describes an interesting and promising method for the manufacture of turbine blades with internal cooling passages. The new method is based on the process of first making the requisite number of holes in a billet, introducing a filler into the holes, hot-working the filled billet by extrusion so that the metal flows and the size and shape of the holes changes, as required, and then removing the filler. According to the invention the holes in the billet are made of annular or other section in such a way that a core is left inside each hole, these holes being made by electric-spark erosion. A filler is then inserted in each hole around the core, and the billet is worked to the desired cross-section. The filler is then removed by acid-leaching and, as the core in each hole is loose, it can also be removed. This process is claimed to have the advantage that the holes can be of any desired cross-section and that, by the use of electric-spark drilling, holes of very small width can be made, so that the total volume of filler required to fill them is small and the time to remove the filler is therefore reduced. Obviously, the filler should have deformation characteristics compatible with those of the metal of the billet. By using a filler in the shape of a preformed metal sleeve, it can be easily inserted into the hole around the core. It is claimed that this method of blade manufacture can be applied, for instance, to gas-turbine blading with longitudinal cooling passages, the blade material consisting principally of nickel-chromium alloy with small percentages of titanium and aluminium.

ENV Double Reduction Axles and Final Drive Units



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VOL. XVII No. 11 NOVEMBER, 1956

Materials in Automobiles of the Future

By A. L. BOEGEHOLD. (From *Metal Progress, U.S.A.*, Vol. 70, No. 3, September 1956, pp. 103–109, 4 illustrations.)

BEFORE considering materials of the future, it is necessary to have some idea of what the future automobile will be, and any prediction must depend on reasonable assumptions. One assumption is that the causes that have operated to produce present-day effects will continue to operate along similar lines, and produce effects in the future from present-day causes. Some of the causes which have been operating in the past are as follows :—

(1) Engineers are naturally desirous of obtaining greater efficiency of transporting personnel and cargo.

(2) Conservation of both fuel and metal resources is a strong urge, and is responsible for part of the desire for greater efficiency, the elimination of strategic materials, the utilization of materials in greater supply, and the use of fuel in a manner consistent with conservation.

(3) These objectives must be attained at a cost which will create an increasing sales volume and standard of living.

Efficiency includes not only the mechanical and thermal efficiency of the power plant, but also the mechanical efficiency of each mechanism in the vehicle and the overall efficiency in terms of resources consumed. As a result, basic requirements are (a) a power plant which is the most efficient to operate and to build, and which needs the smallest quantity of strategic and scarce materials ; and (b) a vehicle of the lowest overall weight compatible with cost and the use of plentiful materials. In this connection, low weight must not sacrifice the present-day roominess of interiors.

PRODUCTION

Consider the statistics for the U.S.A. on population, automobiles, and fuel consumption given in Table I, which includes estimates for 1980. Even though the fuel bill for 1955 has been cut by progressive economies through increased compression ratios and higher-octane petrols, the total fuel consumed in 1980 will be almost double, owing to the increased number of cars and increased mileage per car. An 83% increase in petrol production in the next fifteen years will be very difficult to guarantee. To avoid trouble, another way to reduce fuel consumption, besides more efficient engines, must be found. If each car weighed only half as much, the fuel needed to move it along the road would be considerably decreased. This means that lighter materials of construction must be used, and power plants which have the lowest weight per horsepower developed or selected. This results in using less metal, more of the plentiful metals, and less fuel.

TABLE I

	1930	1940	1955	1980
Number of cars	23,000,000	27,000,000	52,000,000	88,000,000
Population of the U.S.A.	123,000,000	132,000,000	166,000,000	220,000,000
Persons in U.S.A. per car	5·3	4·8	3·2	2·5
Average annual mileage	7200	9200	9600	12,000
Average horse-power	75	125	180	250
Miles per Imp. gallon	18	22	24	36
Imp. gallons of fuel ($\times 10^6$)	11,700	17,500	38,300	70,000

The programme of super-highways can be counted on to force automobile construction in the direction of lower weight and better fuel economy. Highways will very likely be financed by a tax on petrol. As the cost of petrol increases, so will owners turn to cars with lower fuel consumption. This situation in Europe has produced the small car, which, with the generous use of aluminium and magnesium, may weigh about 1600 lb. Although it is unlikely that, in the U.S.A., roominess and comfort will be sacrificed to anything like this extent, American car owners will certainly obtain better fuel economy per ton-mile of operation, resulting from the use of lighter cars.

POWER PLANTS

From comparisons of information available on various power plants, it would appear that the gas turbine (considered by many to be the coming power plant) compares well with the present-day piston engine in weight, occupies less space, and can use low-grade fuel, but much information is needed on how to get along without using scarce alloys such as nickel in the turbine blades. One way to eliminate much of the need for nickel or cobalt in turbine blades would be to keep them at a low enough temperature. This has been done by liquid cooling; however, a condenser and radiator to cool the liquid used for blade cooling are required, and this added complication would sacrifice the weight advantage in favour of the gas turbine. Even though its fuel consumption is on the high side and the exhaust gases must be adequately disposed of, the gas turbine will find uses in certain fields, e.g., sports cars and possibly lorries.

Diesel engines will continue to be used in omnibuses and lorries, because of their low consumption of cheap fuel. A turbo-blower increases both power output and fuel efficiency. Furthermore, although weight is necessary to achieve durability while operating a large percentage of time at nearly full power output, the use of numerous aluminium parts in diesel engines will substantially reduce weight per horsepower and will decrease unit size. Thus, an aluminium diesel would weigh about 7 lb/hp. However, even this would not be suitable for passenger cars, so that, although diesel engines of lighter construction can be designed, developments in this direction should not be anticipated.

The free-piston engine may be a strong competitor to the spark-ignition piston engine for passenger vehicles twenty-five years hence, because it can operate on almost any kind of liquid fuel, it is economical to build, and its fuel economy is nearly as good as that of the diesel.

However, the fact that an engine may be able to burn a lower-grade fuel will probably not be an overriding factor, inasmuch as, even now, the cost advantage enjoyed by kerosene over petrol has all but disappeared.

While the conventional gas turbine uses gas at 1600 to 1700°F, the turbine driven by gas from the free-piston engine operates at 850 to 900°F. The material for turbine blades therefore does not pose a problem of scarce refractory alloys. The advantage of simplicity of the free-piston engine, however, may be lost by the complexity and expense of the turbine needed to produce shaft horsepower. For good efficiency, it must have four or five banks of rotating blades, each with a bank of stationary deflecting blades. This adds greatly to the overall cost of building the whole free-piston-turbine power package. A radial inflow turbine may be the solution here.

The principal advantage remaining in favour of this engine is that it burns low-grade fuels, such as kerosene or mixtures of bunker oil and kerosene. It would appear, therefore, that if free-piston engines ever become the universally used power plant for passenger cars, the output of the petroleum industry would undergo a radical change. In the field of cargo-carrying vehicles, where durability and fuel consumption are important, the free-piston engine will meet competition from the turbo-blown diesel, the regenerative gas turbine, and the high-compression petrol engine made more rugged to stand steady, high-output operation.

Insofar as piston engines are concerned, it is reasonable to assume that, in the foreseeable future, the petroleum industry will be able to provide at filling stations petrol with a sufficiently high octane rating to permit compression ratios as high as 12:1 or 13:1. In this connection, it was demonstrated in 1947 that a car with a 12:1 compression ratio showed a reduction in fuel consumption of at least 30%, compared with cars current at that time with compression ratios of 6:1 or 7:1. With the advent of petrol of a suitably high octane rating for a compression ratio of 13:1, passenger cars will operate with a fuel economy comparable with that of diesel engines and free-piston engines. The fuel, however, will be quite different; it is not at present available at filling stations, and will have an octane rating of 110 to 120.

As a result of improved fuel economy, lower unit weight, and lower unit size, the petrol engine will be in a strong position to retain its place as the power plant of the automobile of the future, particularly if it is constructed with a large proportion of aluminium. Furthermore, it should be remembered that, as practically all manufacturing plants are tooled for this type of engine, the introduction of a radically different type would involve stupendous costs. Nevertheless, these costs would certainly be met if another type of engine were shown to possess definite advantages.

The trend for the next fifteen years, then, would appear to be towards higher compression ratios and the use of more aluminium and magnesium. Ventures involving gas turbines or free-piston engines, probably at first in sports cars, can also be expected, together with the possibility of turbo-supercharging in commercial engines and sports cars, so as to obtain better fuel economy and increased horsepower per unit of size. Passenger cars run at reduced load too much of the time to make turbochargers profitable.

Light Metals

The automobile industry absorbs about 25% of the total production of steel. If a substantial portion of this were replaced with light alloys and plastics in some form, the increasing rate of depletion of iron ores would be given a much needed brake.

Some form of die-cast aluminium cylinder block will be the basis for reducing engine weight, this being a logical extension of the change to aluminium which has already taken place in automatic transmissions. The intake manifold will be of aluminium, but the exhaust manifold will continue to be of cast iron. The pistons, as now, will be made of aluminium alloy, though the low expansion possessed by the present piston alloy may be modified to something compatible with wet aluminium liners, which, of course, will be faced with some wear-resistant material comparable with chromium plate, or better.

Automatic transmissions are accountable for another sizeable increase in aluminium usage. When the total costs of the finished components are compared, aluminium competes with cast iron or malleable iron. Although the cost per pound of aluminium is high, the cost per piece is sliced to one-third, because of its light weight per cubic inch. The cost per cubic inch of iron and aluminium is nearly the same. The machining cost for aluminium is much less, and many parts (which can be made as die castings or permanent mould castings) are closer to finish dimension than iron castings and therefore require less machining.

Another change in the automobile which will lower the weight and save scarce materials will be in the radiator. As copper becomes more expensive and scarcer, the urge to replace it with aluminium will become greater. By 1980, radiators will probably be made of aluminium.

The average 1930 car used 4 lb of aluminium ; by 1945 this had only doubled, but by 1955 it had jumped up to 35 lb. Some cars were using 70 to 80 lb, while one model contained 192 lb, replacing some 400 lb of steel. Hence, a prediction of 80 lb per car by 1965 does not seem unrealistic. Another forecast by a leading engineer in the automobile industry is 100 lb of aluminium in each of the 8,000,000 cars expected to be built in 1970.

The cost per cubic inch of magnesium is higher than that of aluminium, so that the present competition from cast iron has prevented much substitution. However, it may be expected that oil pans and gearbox covers will be of die-cast magnesium.

No mention has been made of titanium, because a legitimate use for it is not envisaged, even if the price were low enough to compete. The structure of the automobile is such that weight can be more easily saved with aluminium and magnesium than with titanium. One possible exception would be for gas-turbine components operating between 500 and 1000°F, where aluminium or magnesium alloys would be inadequate.

With regard to intake and exhaust valves for engines, these will continue to be made of heat-resisting alloys, universally aluminized. Piston pins and connecting rods will probably remain unchanged. Bearings will continue to be steel-backed inserts, made by powder-metallurgy methods.

The crankshaft will be made by the process which will result in the lowest cost without sacrificing any engineering requirement. The two principal contenders seem to be automatic forging of steel, and shell-moulded cast pearlitic malleable iron, or shell-moulded ductile iron. The large investment in automatic forging equipment now existing in some plants constitutes a major obstacle in the path of change to cast crankshafts. The author forecasts, how-

(*Continued on page 468*)

The Testing of High-Voltage Circuit-Breakers

By L. R. Bergström. (From *ASEA Journal*, Vol. 29, No. 6, 1956, pp. 71–81, 12 illustrations.)

In this article, an account is given of tests carried out on ASEA air-blast and contraction circuit-breakers, and of the slightly different test procedure involved in each case. In addition, the conclusions resulting from these tests are indicated.

Of the principal types of high-voltage circuit-breakers, air-blast circuit-breakers and contraction circuit-breakers each have their own inherent advantages which make them especially suitable for different fields of application. The main feature of the contraction circuit-breaker is that it is independent of external means of extinguishing the arc, since it contains in itself the necessary arc-quenching medium. The air-blast circuit-breaker, on the other hand, has to rely upon its supply of air from a special compressor unit, and accordingly, for reasons of cost, is not used for installations with only a few circuit-breakers. When rapid interruption is required, i.e., short opening and arcing times, of particular importance at very high voltages, the air-blast circuit-breaker is at present superior. Furthermore, it is far easier to solve the problem of interrupting an unloaded line and reactor-loaded transformers with air-blast circuit-breakers.

Air-Blast Circuit-Breakers

Since air-blast circuit-breakers for high breaking capacities are built up of series-connected breaks, " unit " testing can be used for determining the maximum breaking capacity. Unit testing implies that one break (or a pair of breaks) is tested with the full breaking current and with that proportion of the breaking voltage which the break would obtain if the whole circuit-breaker were tested on a full scale. If the circuit-breaker is provided with n breaks and one of these can be tested with a breaking power P_1, the total breaking power of the breaker will be nP_1. In this way, it is usually possible to attain the guaranteed breaking capacity for the whole breaker.

When carrying out the unit test, it is naturally assumed that the voltage is evenly distributed across the different breaks, i.e., that the breaker under real service conditions will obtain the same voltage across each break. In order to ensure that this condition will be fulfilled, the circuit-breakers are provided with grading resistors, which are so designed that the current through them will be considerably greater than that through the capacitances to earth of the breaker. How earth capacitance affects a breaker with two series-connected breaks is shown in Fig. 1, in which C is the capacitance across each break and C_1 the capacitance to earth on the free connection between the breaks. C_1 is normally considerably greater than C. With, for example, $C_1 = 5C$, which is a reasonable value, the ratio between the voltages across the two breaks u_a and u_b at a short-circuit interruption will be

$$u_a/u_b = (C + C_1)/C = 6$$

since the short-circuit implies that the capacitance C on the break b is connected in parallel with C_1. Thus, this means that $^6/_7$ of the voltage U is applied across the break a and $^1/_7$ across b. The voltage distribution in this case will therefore be very uneven, and as a rule the voltage is, in fact, very unevenly distributed in all circuit-breakers with series-connected breaks, unless steps are taken to control the voltage distribution. If grading resistors with resistances of the same magnitude are connected in across each break in Fig. 1, the voltage can also be evenly distributed at high frequencies of the recovery voltage. The combination of capacitances and resistances, as can easily be perceived, makes the voltages u_a and u_b dependent upon the frequency, since the voltage drop across the capacitance C is a function of ωC, where ω is the angular frequency, while the voltage drop across the resistor is independent of the frequency. In the case of a breaker with many series-connected breaks, the calculation of a suitable resistance for the grading resistors is a complicated matter. It is usually the practice to measure the capacitances on the breaker and then to transfer the values obtained, suitably scaled down, to an electrical model of the circuit-breaker. The voltage distribution is then measured on this model at those frequencies which might be applicable to the breaker, and the resistance in the grading resistors which provides a sufficiently even voltage distribution across all the breaks is then selected. The voltage distribution is also measured during the breaking tests, in order to check that the equipment has been correctly dimensioned. As a rule, however, it is possible to select resistances with such low values that there will be no doubt whatsoever that the voltage is correctly distributed. There have been certain speculations as to whether the voltage distribution might be impaired by the small amount of residual current which, immediately after breaking, flows through the path previously taken by the arc. Hitherto, none of the results obtained has shown that this is the case, and theoretical studies indicate that, even if this leakage current has any influence, the voltage distribution should be improved.

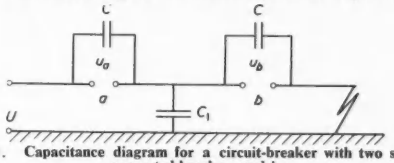


Fig. 1. Capacitance diagram for a circuit-breaker with two series-connected breaks a and b.

The voltage distribution can also be improved by using grading capacitors connected across each break. Referring again to the previous discussion in connection with Fig. 1, it is apparent that a considerably greater grading capacitance than the capacitance to earth is necessary. Where the dimensioning of the grading capacitances is concerned, it is not feasible to use ample ratings, as is the case with the grading resistors, and the voltage distribution must be more accurately measured.

The decisive factor in the design of a circuit-breaker is, above all, its capacity to interrupt a certain (as a rule, very high) short-circuit power. Tests for determining the maximum breaking capacity are consequently very important. Such unit tests are carried out as single-phase tests on circuit-breakers for high breaking capacities, and the recovery voltage, i.e., the supply-frequency component of the voltage which appears across the circuit-breaker after interruption, is so chosen that it corresponds to the voltage of the first phase to clear a three-phase short-circuit. In a system which has either a free neutral, or a neutral earthed through an arc-suppression coil, the recovery voltage for the first phase to clear will be 1·5 times the phase voltage, while that for an effectively earthed neutral system will be less than 1·3 times the phase voltage.

Air-blast circuit-breakers are sensitive to the rate of rise of the recovery voltage, and tests must be carried out with a rate of rise which corresponds to that which the breaker can be exposed to during service. However, the rate of rise does not usually create any difficulties for breakers with many series-connected breaks. The rate of rise for which each break is tested is, in fact, only $1/n$ of the rate of rise to which the whole breaker is subjected. In the majority of cases, it is possible to obtain a sufficiently high voltage for one break in the laboratory, even for tests with the highest breaking currents.

In addition to tests with the highest guaranteed breaking current, tests are also made with 60, 30, and 10% of this current and with an asymmetrical current as laid down in different specifications for circuit-breakers. Tests with very small currents, strange as it may seem, are not suitable or even possible to carry out in the laboratory, both because the whole circuit-breaker must be connected up, which would mean that the voltage for breakers for the highest service voltages would be greater than that which can be produced in the laboratory, and because the interruption of capacitive currents must also be investigated. Naturally, a considerable number of tests may be made, which more or less simulate the real voltage stresses but, in order to judge correctly the ability of the circuit-breakers to interrupt small currents, field tests on actual installations under service conditions are necessary. A considerable number of such tests has been carried out in Sweden between 1948 and 1955 on circuit-breakers for 220 and 380 kV. The results of these tests have been very encouraging, and show, above all, that non-linear protective resistors, connected across the whole breaker and without any links to the different breaks, are an effective means of keeping down the over-voltages which arise when small inductive currents are interrupted. The tests also prove that the breakers will interrupt an unloaded transmission line without the risk of restriking, thereby eliminating the occurrence of over-voltages.

Special Laboratory Tests and Investigations:—

Before it is possible to carry out field tests on a circuit-breaker, there are several investigations which can, and should, be made in order to be absolutely sure that the circuit-breaker will not be damaged by the extreme voltage stresses which occur during field tests. Naturally, these investigations are also important as regards the tests which are carried out for determining the breaking capacity at high power values. When an unloaded transmission line is interrupted, the current is broken at current zero, and the voltage on the line has its peak value at this moment. When the current is broken, the line is disconnected from its supply and, since the line acts as a capacitance, it remains charged with the voltage it had at the moment of interruption. On the station side of the breaker, the voltage, however, changes with the supply frequency, and half a cycle after the interruption has taken place the station voltage has reached its peak value with the opposite polarity. The voltage across the breaker will then be double the amplitude of the voltage before the interruption. Moreover, it is necessary to take into consideration the fact that the voltage before the interruption can become much greater than the normal service voltage, owing to the voltage rise which occurs if a line suddenly becomes unloaded when the station connected to the end of the line is disconnected. In this way, the voltage across the breaker can be considerably greater than that for a short-circuit interruption. When, for example, an interruption occurs in a 380-kV line, the voltage can increase from 400 kV to 540 kV, and the amplitude of the voltage across the breaker will be not less than 740 kV, compared with 430 kV for a short-circuit interruption. The breaker must not restrike during the period from the separation of the breaking contacts to the opening of the series-connected isolators.

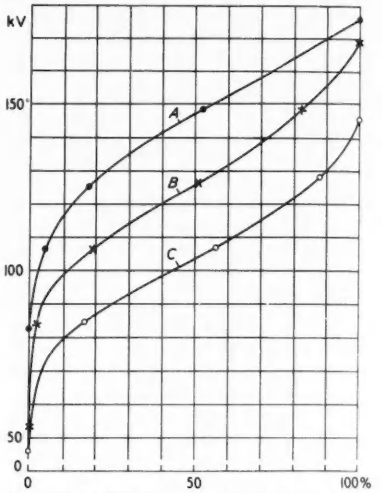


Fig. 2. **Influence of different contact designs *A*, *B*, and *C* on the flash-over voltage between the contacts for a break of an air-blast circuit-breaker.**
Note:—The abscissa denotes the time during which the voltage does not exceed a certain value expressed as a percentage of the whole period in which the contacts are open.

In order to investigate the dielectric strength of the breaks when the contacts are open, tests are carried out with such a high direct voltage that flash-over occurs between the contacts. When flash-over takes place, the voltage drops and the discharge is extinguished, whereupon the voltage rises again until flash-over occurs once more. An oscillogram is taken of the voltage and has the shape of a saw-tooth curve. Many interesting and important observations can be made from such curves. It can be seen, for example, that the dispersion of the flash-over dielectric strength is considerable. Fig. 2 shows the distribution of the flash-over values, obtained in this way, for three different contact designs. From this it can be noted that the ratio between the highest and lowest flash-over values is very considerable. This in itself is not surprising. The explanation is to be found both in the extensive dispersion of the flash-over values in compressed air, and in the change in the air density taking place due to air flow. These curves are mainly used for studying the influence of different design factors, such as the contact gap and the shape of the contacts, on the dielectric strength.

In addition to these tests, measurements are also carried out in an electrolytic tank. In this way, a series of equipotential curves is obtained (Fig. 3), which illustrates how the electrical field is distributed between the contacts. It is thus possible to determine which contacts, with regard to the field distribution, are the most advantageous. The shape of a contact, however, also influences the air flow and this, in its turn, affects the dielectric strength. As a rule, therefore, it is necessary to compromise between different types of contact which

are most suitable from the point of view of electrical and flow conditions.

Certain investigations regarding pneumatic cycles and allied problems can be carried out in the laboratory. These cycles are rather complicated, and it is necessary to make both theoretical and experimental investigations in order to understand them fully. It is mainly a question of rapid filling and discharging. Pronounced oscillations also occur, since the passages are often long, especially in circuit-breakers for very high voltages.

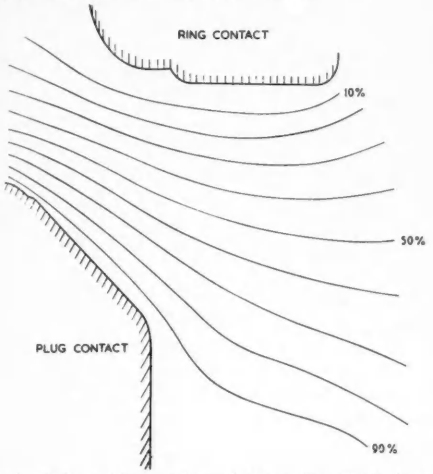


Fig. 3. **Equipotential curves illustrating the voltage distribution in a break of an air-blast circuit-breaker.**

In addition, the air flow, with its changes in density, eddies, etc., can also be investigated in the laboratory by means of Schlieren photographs. The results which have been obtained with Schlieren measurements provide useful information about the influence of the shape of the contacts and also of the other circuit-breaker parts upon the air flow. Fig. 4 is a Schlieren photograph of the air flow in a break of an air-blast circuit-breaker for 132 kV.

Interruption of Small Inductive Currents:—

When the interruption of small inductive currents takes place, the current, instead of following its normal sinusoidal curve towards zero, can become more or less chopped and goes prematurely towards the zero line. This results in over-voltages which become greater, as the cutting-off of the curve becomes more effective and the chopping current increases. The magnitude of the over-voltage is also dependent upon the network where the interruption occurs.

With the interruption of small inductive currents, this cutting off of the current and the resulting over-voltages take place in all types of circuit-breakers. In most cases, the over-voltages are fairly small and harmless but, especially with breakers for very high service voltages, all appreciable over-voltages must be prevented, and therefore special steps must be taken to reduce them. It is impossible to construct the breaks in such a way that over-voltages will be eliminated, since the breaker, in order to fulfil its other functions, must have a large dielectric strength after the interruption, and thus cannot itself limit the over-voltage. The best solution is to provide the breaker with non-linear protective resistors, since it is desired to have a relatively large current through the resistors when the over-voltages arise, but a low current

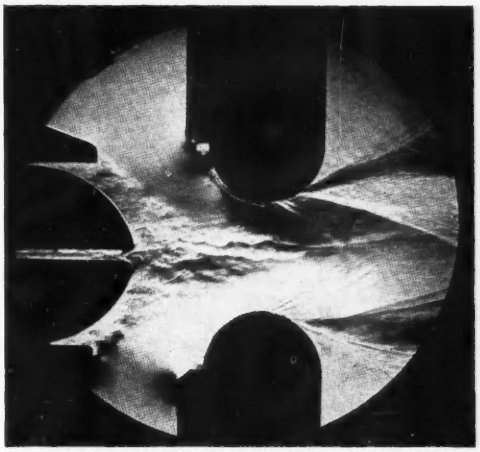


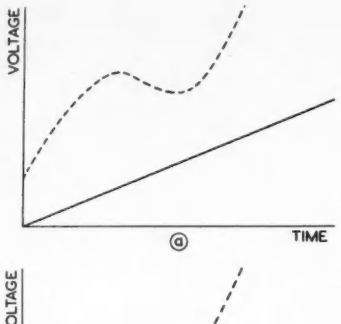
Fig. 4. **Scpieren photograph of air flow in a break of an air-blast circuit-breaker for 132 kV.**
The plug contact is on the left and the ring contact in the middle. The direction of air flow is from left to right.

at normal voltage, so that the series-connected isolators of the breaker will have no difficulty in interrupting the resistance current.

Rate of Rise of Recovery Voltage:—

When a normal short-circuit interruption occurs, the arc is extinguished at the current zero, and the breaker must prevent re-ignition of the arc. The previous arc path must thus within a very short time regain a dielectric strength sufficient to withstand the recovery voltage across the contacts. The quicker the voltage recovers, the less time the arc path has to regain sufficient dielectric strength. Thus, it is obvious that the rate of rise of the recovery voltage plays an important role in connection with the breaking capacity, and this is especially the case with air-blast circuit-breakers. How the rate of rise is to be calculated and which values it can take for different networks, and similarly how much it influences the breaking capacity of different breakers, have been thoroughly investigated. On the other hand, no detailed investigations have been made as regards the influence of the rate of rise on the breaking capacity. The simple concept of a race between the recovery voltage and the dielectric strength of the path is not quite correct, since it has been shown that the dielectric strength of the path itself is dependent upon the recovery voltage. By proceeding from certain assumptions, of which the most important is that the dielectric strength of the path is entirely determined by the varying density due to the temperature, it is possible to make qualitative studies of the influence of the recovery voltage, with regard to its shape as well as its rate of rise. Fig. 5a illustrates the appearance of the recovery dielectric strength for a linearly rising recovery voltage u_r. Fig. 5b shows that, if the otherwise linearly rising recovery voltage u_r, at the beginning of its sequence, has a steeper section than before, the recovery dielectric strength will be so reduced that the curves cross one another, which means that re-ignition of the arc will take place. This would correspond most closely to the case when the restriking voltage has a harmonic with a far higher frequency than that of the fundamental.

Special circuit-breakers for low voltages, 20 kV and below, are used in installations where the rates of rise



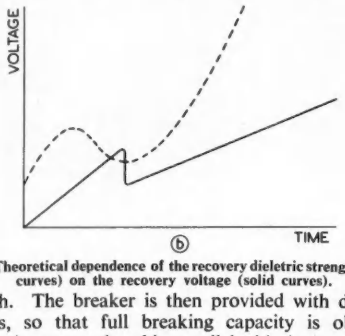


Fig. 5. Theoretical dependence of the recovery dieletric strength (dotted curves) on the recovery voltage (solid curves).

are high. The breaker is then provided with damping resistors, so that full breaking capacity is obtained. These resistors are placed in parallel with the breaker and are connected in by means of an auxiliary arc. They differ considerably from the grading and protective resistors described previously, and are always linear and have a resistance of the order of 10 ohms. The resistors damp the recovery-voltage oscillations aperiodically, and the rate of rise is thus kept low and independent of the network.

Phase-Opposition Interruption:—

Circuit-breakers used for very high voltages are occasionally required to be able to interrupt under phase-opposition conditions. This signifies that the voltages across the breaker can be as high as twice the service voltage. However, it is still not quite certain which voltages and currents will be encountered with phase opposition. In order that the voltage may be double the service voltage, the voltages on both sides of the breaker must have a phase difference of 180 deg. It has therefore been claimed that 1·6 times the service voltage is sufficient, which implies that the networks are considered not to be completely out of phase during the interruption sequence. The generally proposed value for the current at a phase opposition interruption is 50% of the rated breaking current for the breaker, but 25% has also been suggested. If single-phase tests are carried out, it is necessary to select, as is the case with normal breaking tests, either the factor 1·5 for networks with free neutral or earthed through an arc suppression coil, or 1·3 for effectively earthed networks. The rate of rise of the recovery voltage should be the same as that for the normal breaking tests at full breaking power.

CONTRACTION CIRCUIT-BREAKERS

In the ASEA oil-minimum type of circuit-breaker, provided with contraction chambers, an arc arises when the contacts are separated, causing the oil in the upper part of the chamber to vaporize. The pressure set up by the oil vapour is transmitted to the lower compartment of the chamber, where it is increased by the action of a differential piston in direct proportion to the ratio of the upper and lower effective piston areas. The contact plug in its movement downwards uncovers the passages in the central part of the differential piston, and, owing to the difference of pressure between the two compartments, the oil will flow rapidly in the direction of the pressure drop and is forced in against the vapour envelope surrounding the arc. At the same time, the arc gases escape from the chamber through the bore in the moving contact plug and through several spring-loaded safety valves fitted in the top of the contraction chamber. In this way, a powerful flow of vapour is forced along the path of the arc. When the current wave approaches zero, the generation of heat and vapour subsides, but the piston will still continue to move, owing to the pressure which remains and to its own inertia. Thus, the flow of oil does not entirely cease. The generation of vapour continues as a result of thermal inertia, and in this way a high speed and a high static pressure of the arc gases flowing along the arc path will be maintained during the process of de-ionization. When the interruption is completed, the oil will continue to flow, and thus a puncture-proof layer of oil is rapidly obtained between the contacts.

To enable the current to be broken, it is obvious that an intensive flow along the arc at the current zero is necessary. Fortunately, it so happens that this flow becomes especially intensive when the current is high. This is apparent from the fact that the arcing times at a given voltage decrease with an increasing current. The minimum arcing time which can be obtained is determined by the geometrical shape of the contraction chamber, and it is especially the time taken for the plug to uncover the passages in the central compartment of the piston which is the decisive factor. In addition, consideration must be paid to the time which elapses, because the current must be broken at its current zero. If the passages are uncovered just at the moment of a current zero, the breaker should be able to interrupt the current. If the arcing time is extended, i.e., the current zero comes later, the energy developed will increase, thereby causing the pressure to rise. This high pressure is not necessary for the extinction of the arc, but, on the other hand, cannot be avoided, and thus the chamber must be designed for a higher pressure than that which corresponds to the most favourable interruption. The mechanical strength of the chamber is of considerable importance for the breaking capacity. The insulating material in the pistons, in particular, has great demands placed on it, both from a mechanical and an electrical point of view.

Testing with High Breaking Power:—

If it is required to carry out a high breaking capacity test in the laboratory, the desired breaking current can only be obtained with a greatly reduced breaking voltage. The unit test, which previously proved to be very practical for air-blast circuit-breakers, cannot be employed, since a contraction circuit-breaker with only one break must as a rule be able to interrupt a considerably higher power than that available in the laboratory. This means that it is not sufficient to provide a pressure and vapour generation which are just adequate to interrupt the current at the recovery voltage used during the test, but that the pressure must be considerably greater, so that there will be no doubt as to whether the higher recovery voltage which occurs during actual breaking conditions will be mastered. In order to be sure that this will be the case, the piston movements obtained when testing at full current and reduced voltage are compared with

the piston movements obtained when testing at full voltage and reduced current. The movement and speed of the piston, which are indirectly an indication of the pressure and vapour generation, are measured during the interruptions, giving a good idea of how the breaker will function when interrupting a full current at full voltage.

In order to ascertain how satisfactory is the design of the contraction chamber, it is necessary to carry out tests in plants which can provide a higher short-circuit power. These tests are very troublesome and expensive, but, despite this, they must be used occasionally in order to check that testing methods and the results obtained from them are satisfactory. Tests with very high power values have been carried out on contraction circuit-breakers in Sweden in 1951, the U.S.A. in 1953, and Holland in 1955. Based on the results of these tests, curves showing arcing time as a function of current at a given recovery voltage, and of recovery voltage at a given current, have been plotted. These curves establish that, when the current increases, the arcing time decreases, and that the same result is obtained, independent of the recovery voltage. Furthermore, it is apparent that arcing time is independent of recovery voltage at high currents. Since the stresses on the extinguishing chamber depend on the duration of the arc in the chamber, they will obviously be dependent only on the magnitude of the current at high breaking power values.

As it is of great importance that the stresses on the chamber do not become excessive, certain investigations were carried out to ascertain what happens if arcing time is prolonged artificially. A special circuit was used for this purpose, in which a capacitor was charged up to a certain voltage and discharged through the breaker at the current zero when interruption would normally take place. The most remarkable result of these investigations, which were made on a 132-kV circuit-breaker, showed that it was, on the whole, very difficult to obtain a flash-over between the contacts, and that the voltage had to be raised to a higher value than that corresponding to the full breaking voltage before it became possible to obtain a prolonged arcing time. In addition, the stresses on the chamber were not alarmingly high, despite the prolonged arcing time, but the breaking current was not the maximum possible during these tests. The fact that a very high voltage is needed to enable the arc to restrike shows that the testing method previously described for comparing the movement of the piston under different breaking conditions is practical.

(*Concluded on page 492*)

U.S.A.

Gallium

By H. P. BONEBRAKE. (From *Metal Progress*, Vol. 70, No. 2, August 1956, pp. 105–106, 1 illustration.)

GALLIUM is a silvery white metal, which melts at 86°F and remains in the liquid state up to approximately 3600°F. This extremely wide liquid range prompted de Boisbaudran, who discovered gallium in 1875, to suggest its first application as a replacement for mercury in high-temperature thermometers. In its latest use, liquid gallium is an effective sealant for glass joints and valves in vacuum equipment, and has more than doubled the operating time of a ground-glass joint.

When atomic-energy power plants became a probability, the long liquid range and low vapour pressure of gallium suggested its use as a heat-exchange medium, but the metal's trait of "wetting" almost everything, including glass, has been in the way of this proposal. Even though this property appears to be due to traces of oxide in the gallium or on the object, truly oxygen-free conditions are very difficult to produce and maintain. The greatest drawback of gallium, however, is that, at elevated temperatures, it attacks solid metals and can be contained only by quartz, graphite, alumina, and some other refractory oxides, and the metals tungsten and tantalum. The ability of gallium to reflect a high percentage of incident light led to its limited use as a backing for optical mirrors.

As one of the few metallic elements having greater density as a liquid than when solid, gallium presents an interesting packaging problem. Loss or contamination of shipments may be prevented by packaging liquid gallium in rubber bulbs and plastic capsules to allow for the 3·1% expansion of volume on freezing. This unusual characteristic has suggested that gallium can be used to obtain high pressures at low temperatures; it also improves its efficiency as a sealant in vacuum equipment.

Experiments with gallium as an alloying material have shown that a small amount increases the hardness of ternary aluminium alloys. Recent tests indicate that, in severely corrosive environments, gallium improves the resistance to corrosion of commercially pure magnesium and of a Mg-Sn binary alloy. Its most successful application, however, has been in gold alloys used in dental work. In a test of strength, such an alloy, mixed in a mortar and pestle and formed into a filling, exhibited a strength of 66,000 psi.

However, these and other uses have generated only a small demand for the metal, the cost of which is high because of the complicated processing methods required to produce it.

Gallium occurs only in minute quantities in bauxite, zinc ores, and in coal. It may be refined from the Bayer-process solution as a by-product in making alumina, the feed for the electrolytic cells producing aluminium metal. It may also be extracted from the residues of zinc distillation plants. It has been estimated that 2,000,000 lb of gallium are left behind in the ash and soot of coal burned yearly in Great Britain. The gallium-rich residues are concentrated and refined chemically into a solution in caustic soda, and then electrolysed between insoluble anodes. The gallium drips off the cathode. Later purification depends on the fact that gallium may be supercooled some 50°C below its real freezing point. The supercooled metal is seeded with a small crystal of gallium and the crystal grows rapidly, the impurities tending to remain in the liquid. When most of the liquid has crystallized, the solid is removed, and the process repeated until the desired purity is reached. This process has certain similarities to the "zone-refining" methods for producing germanium crystals for transistors.

U. S. A.

Principles and Characteristics of Solar Furnaces

By G. Benveniste and N. K. Hiester. (From *Mechanical Engineering*, Vol. 78, No. 10, October 1956, pp. 915–920, 7 illustrations.)

Although the principles of the solar furnace were known and even applied over 2000 years ago, and reasonably efficient furnaces were constructed in the 17th and 18th centuries, the present era of modern furnaces probably dates from 1909. *Since then, numerous solar furnaces have been constructed and have established themselves as practical sources of intense heat for use in research and industrial processes.*

Outside the atmosphere, the sun yields 1·35 kW/m². This figure, known as the solar constant, varies by about ± 3·5%, owing to the elliptical nature of the earth's orbit, and ± 1·5% as a result of solar disturbances, e.g., sunspots. Not all of this energy, however, reaches the surface of the earth, some being scattered or absorbed by gas and air molecules and by particles in the atmosphere. The amount of energy available at noon on a clear day on a surface perpendicular to the sun's rays varies with the season, the altitude, the latitude, and the clearness of the sky at the site. However, in many parts of the U.S.A., this figure, as a rough approximation, may be assumed to vary between 0·8 to 1·1 kW/m².

The amount of energy per unit area e_0 [W/cm²] available at the site of the furnace at any moment is

$$e_0 = S\eta_a \quad .. \quad .. \quad .. \quad .. \quad (1)$$

where S is the solar constant and η_a is the efficiency of transmission of direct solar radiation through the atmosphere of the earth,

Concentration Ratio and Actual Furnace Efficiency

While lenses have been used in the past, their cost has made them virtually prohibitive in modern solar-furnace construction, and practically all high-temperature furnaces are now paraboloids. With a parabolic reflector it is possible to concentrate the heat flux available at the site of the furnace so as to obtain in practice a flux sufficient to maintain temperatures above 3000°C. The concentration ratio and the concentration efficiency of a furnace are important parameters which permit evaluation of the heat flux and the temperatures available on the target at the focus of the paraboloid.

The sun is not a true point-source of light. Its apparent diameter, as seen from the surface of the earth, is about 32 min of arc. This means that the sun's rays are not quite parallel, and for each point on a parabolic mirror the incident and therefore the reflected beams are not single beams, as in the case of parallel rays, but cones with an apex angle of 32 min.

With a typical parabolic mirror, only the central beam forms a circular image of the sun at the focus of the paraboloid. All the other reflected cones form ellipses which are more or less pronounced according to the angle of incidence of the beam on the target. The diameter d of the circular image of the sun depends only on the focal length f of the paraboloid and is given by

$$d = 2f \tan 0° 16' = f/107·3 \quad .. \quad (2)$$

This characteristic of solar furnaces limits the ultimate concentration ratio obtainable. As the ratio of the aperture or diameter D of the furnace to its focal length f is increased, more and more solar energy is concentrated on the target from points on the mirror subtending large rim angles and causing very pronounced ellipses around the solar image. As the rim angle θ approaches 90 deg., increasingly less additional energy is concentrated on the solar image. When the rim angle reaches 90 deg., no additional components of energy can reach a flat target.

Assuming that the efficiency factor $\eta_{ar} = \eta_a\eta_r$, where η_r = the efficiency of reflection of sunlight on various surfaces of the furnace, the total amount of energy E reaching the circular image of the sun is given by

$$E = \pi\eta_{ar}Sf^2 \sin^2\theta \quad .. \quad .. \quad .. \quad (3)$$

or, from eq. (1),

$$E = \pi\eta_r e_0 f^2 \sin^2\theta \quad .. \quad .. \quad .. \quad (4)$$

The heat flux per unit area within the sun's image is a more useful concept and, since the image area of the sun, from eq. (2), is $\pi(f/214·6)^2$, the heat flux per unit area e within the sun's image is given by

$$e = \eta_r e_0(214·6)^2 \sin^2\theta = 46·1 \times 10^3\, \eta_r e_0 \sin^2\theta \quad (5)$$

The concentration ratio C_r is the ratio by which the energy available at the site of the furnace is concentrated on the sun's image at the focus of the paraboloid, so that

$$C_r = e/e_0 = 46·1 \times 10^3\, \eta_r \sin^2\theta \quad .. \quad .. \quad (6)$$

The theoretical concentration ratio C is the concentration ratio independent of the efficiency of reflectivity η_r, so that

$$C = 46·1 \times 10^3 \sin^2\theta \quad .. \quad .. \quad (7)$$

Another interesting concept deals with that percentage of energy incident on the surface of the furnace which is theoretically concentrated on the area of the sun's image. This percentage η_c, the theoretical concentration efficiency, is independent of the efficiency of reflectivity η_r, and is given by

$$\eta c = \left(\frac{1 + \cos\theta}{2}\right)^2 \quad .. \quad .. \quad (8)$$

These concepts permit the examination of the performance of paraboloids with varying rim angles and different ratios of diameter D to focal length f. Fig. 1 shows that, as the rim angle of the furnace is increased, the theoretical concentration ratio C also increases, reaching a maximum of 46,100 for a flat target and for a rim angle of 90 deg. It is significant that the theoretical concentration efficiency decreases with an increase in rim angle θ ; in other words, it becomes more difficult to concentrate energy in the area of the sun's image. A furnace with a rim angle of 30 deg. is theoretically capable of concentrating 87% of the energy incident on the furnace on the sun's image, while a furnace with a rim angle of 70 deg. concentrates only 45% of the energy incident on the sun's image.

In addition to the theoretical concentration efficiency η_c, the efficiency of transmission through the atmosphere η_a, and the efficiency of reflectivity of the surfaces of the furnace η_r, the imperfections of a mirror or furnace as an efficiency factor η_f and the efficiency of absorption of light by the target as η_t should also be considered. The total efficiency η with which the solar constant S is concentrated and absorbed by the target is therefore

$$\eta = \eta_c\eta_r\eta_f\eta_t\eta_a \quad .. \quad .. \quad .. \quad (9)$$

and the flux e_t available to heat the target is

$$e_t = 46{\cdot}1 \times 10^3 \, \eta S \sin^2 \theta \quad .. \quad .. \quad (10)$$

Temperature

When a target is located at the focus of a paraboloid, it will reach an equilibrium temperature which depends on the available flux e_t and on the conduction, convection, and re-radiation heat losses of the target. At high temperatures, conduction and convection losses are less important than radiation losses. At certain temperatures a black body radiates heat fluxes, which are a function of the fourth power of the temperature, ranging from 29 W/cm² at 1500°K to 91 at 2000°K, 462 at 3000°K, 1456 at 4000°K, 3568 at 5000°K, and 7392 at 6000°K.

It should be possible, in theory, to obtain with a theoretical maximum-concentration ratio of 46,100 and with, say, 1 kW/m² at the site of the furnace a heat flux e_t of about 4610 W/cm². With this flux an equilibrium temperature above 5000°K could be expected. In practice, the losses caused by reflectivity η_r, the imperfections of the furnace η_f, and the efficiency of absorption of energy by the target η_t result in lower operating temperatures, of the order of 3500°K. In addition, all the furnaces built to date have rim angles which are less than 90 deg. and theoretical concentration ratios lower than 46,100.

In this respect it is important to stress the fact that none of the furnaces so far built has reached temperatures above 3500°C. This temperature corresponds to an equilibrium heat flux of about 1000 W/cm², if conduction and convection losses are disregarded. At these temperatures these losses may still amount to one-third of all losses, and the equilibrium heat flux may therefore be closer to 1400 W/cm². Most modern furnaces are designed to yield higher flux densities, in some cases even reaching above 3000 W/cm², but in practice geometrical imperfections and reflectivity of the target keep the actual maximum heat flux absorbed by the target closer to 1400 W/cm².

Physical Arrangements

To use a solar furnace effectively, attention must be given to many details such as physical mountings, sun-tracking mechanisms, target holders, control mechanisms, and auxiliary laboratories.

Tracking the Sun :—

Arrangements must be provided to follow the sun during the day and during the seasons. With a single parabolic surface it is possible to have the paraboloid rotate on a single support, while the focus moves in space above the mirror. It is also possible to have a stationary focus in space and a mirror so supported that it may be moved easily to maintain the focus stationary. Usually, in large units auxiliary mirrors are used to facilitate access to a stationary focus. Auxiliary mirrors in this case are usually simpler to operate and actually less expensive than the delicate and sturdy mechanisms which must be provided to rotate accurately the entire paraboloid and focus.

Heating the Target :—

A substance to be melted can be placed in the focus of the furnace and can be supported outside the focus. For certain experiments this simple set-up is adequate. In some instances it is preferable to make the substance move slowly, so that the molten product is removed from the zone of high temperature and fresh unmelted

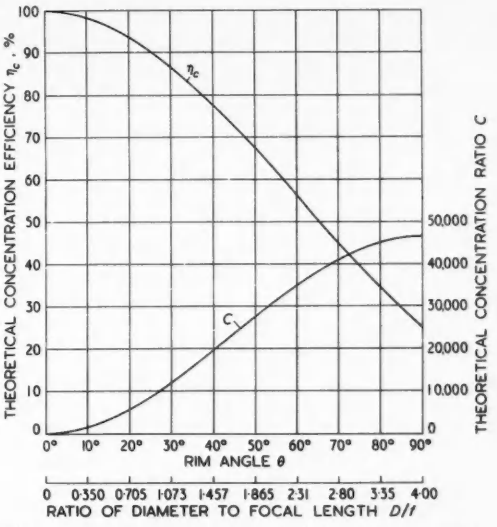


Fig. 1. **Theoretical concentration ratio C and theoretical concentration efficiency η_c as a function of rim angle θ and of ratio of diameter D to focal length f for a parabolic solar furnace.**

material brought in. When, for example, zirconium oxide is melted, the thermal conductivity of the molten surface is low and reduces the speed of the operation, unless the substance is displaced and a new non-melted surface exposed. This operation is performed with a carriage on small wheels, if powders are used, or with any other suitable arrangement, depending on the characteristics of the substance to be treated.

Another technique consists of feeding a powder by gravity to the focus of the furnace, where it is melted or sintered, then solidified, and slowly and continuously removed from the focus.

These mountings require a certain amount of elbow room and space in which to work. The great advantages of having a stationary focus of direct access are apparent. All these operations can be performed in uncontaminated atmospheres, in the air, or in an oxidizing atmosphere. Special techniques permit performance of operations in a conditioned atmosphere.

Surface melting is effective with materials having a good capacity for absorbing solar radiations. Other materials are best treated in special black-body furnaces, which consist of an insulated cavity with an opening of approximately 100 deg., through which the radiations can enter. Black-body furnaces developed at the Mont Louis laboratory in France are water-cooled and can be rotated at speeds up to 5000 rpm. They permit purifying operations at high temperature levels.

Temperature and Flux Control :—

Control of temperatures and flux is obtained relatively simply by shielding part of the surface of the focus some distance away. In this manner the quantity of sunlight and the flux available can be increased or decreased, as desired. Temperature and flux measurements naturally can be performed with conventional means, such as optical pyrometers and water-cooled black-body cavities. Care must be taken in using optical pyrometers to distinguish between the direct radiation from the specimen that must be measured and reflected-sunlight radiations which may cause appreciable errors in the measurements.

Characteristics of Some Modern Solar Furnaces

Important solar-furnace installations are located at Mont Louis in the Pyrenees, where a comprehensive laboratory, including six small furnaces of 5 ft diameter and one large 35-ft unit, has been established. All these furnaces use auxiliary mirrors to track the sun. The large unit is vertical and the targets are therefore exposed sideways, while five of the small units are so arranged that the parabolic mirror is above the target and specimens can be exposed directly from above. The main difference between the small units and the 35-ft unit is that the latter, which has a focal length f of 19·7 ft, a theoretical concentration ratio C of 26,000, and an available flux density e_t at the image of about 1820 W/cm², has a surface which actually consists of approximately 3500 small mirrors so arranged and curved that they form part of a large paraboloid surface. The smaller units were adapted from army searchlight mirrors and are in one piece. Similarly, all the auxiliary heliostat mirrors used consist of many smaller mirrors on one frame.

These furnaces have been used in many high-temperature research programmes, which have been performed in oxidizing atmospheres and also in controlled atmospheres with special quartz containers. High-temperature refractory materials have been purified with extremely good results, and the furnaces have been used in the production of cermets and other special alloys. Work also has been done with high-temperature-equilibria reactions, such as the fixation of nitrogen.

The success of these programmes has led the Centre National de la Recherche Scientifique to project a new furnace with a diameter of 200 ft. This unit, which will have an equivalent input capacity of about 1000 kW and will be located near the existing laboratories, will be used in industrial programmes sponsored on a co-operative basis by French industry and the French Government.

In another furnace, built at Bouzareah, near Algiers, for use in nitrogen-fixation processes and high-temperature research, no auxiliary mirror is used. The surface of the paraboloid, which has an outside diameter of about 28 ft, consists of 144 aluminium reflecting elements, especially electro-polished for high reflectivity. The supports of the paraboloid, similar to those used for astronomical installations, permit the reflector to be oriented so that it can track the sun during the day. Although this unit, which has a focal length of 10·3 ft, a theoretical concentration ratio of 40,000, and an available flux density of about 3200 W/cm², is designed for higher temperatures than the 35-ft furnace at Mont Louis, its cost is disproportionately higher, the difference being due mainly to the simplicity of the Mont Louis design.

The National Physical Laboratory of India has built a slightly different furnace of lower flux intensity and a maximum concentration ratio of 192, comprising an array of 192 mirrors, each of 1 sq ft, concentrating on a single target of 1 sq ft. Small 5-ft furnaces also exist at the Solar Laboratory of the USSR Academy of Sciences, and at the Government Research Institute at Nagoya, Japan, while one is being projected in Australia at the New South Wales University of Technology in Sydney.

In the U.S.A. several 5-ft units, often utilizing converted army searchlight mirrors, have been constructed. In addition, a range of solar furnaces, with diameters ranging from 5 to 10 ft, is available commercially. In general, these units do not use auxiliary mirrors and have been built with searchlight mirrors or specially prepared aluminium sheets. One typical 10-ft unit of this type has a focal length of 2·83 ft, a theoretical concentration ratio of 45,000, and an available flux density of about 600 W/cm².

The first U.S. furnace, built in 1932 at the California Institute of Technology, is remarkable in that it utilizes lenses instead of a parabolic surface. This unit, with a theoretical concentration ratio of 20,000 and an available flux density of about 1200 W/cm², uses 19 lenses, each 2 ft in diameter, to collect energy over a total area of approximately 57 sq ft, this energy being brought to the focal point by 19 secondary lenses and 18 oblique mirrors. The unit is mounted in the same way as an astronomical telescope, with rotation around the earth axis and a declination axis, the focal point remaining fixed, since it is at the intersection of these two axes.

Applications of Solar Furnaces

Solar furnaces are definitely useful tools for high-temperature work up to between 3000 and 3500°C, enabling experiments to be carried out under conditions where lack of contamination from flames, combustion products, electrodes, and refractory fragments is of importance. Furthermore, there can be no doubt that, as the need for new high-temperature materials becomes more pressing, the solar furnace will be of great value in the research and development of such materials and their industrial application. In this connection, it is interesting to note that the proposed construction of a 200-ft solar furnace near Alamogordo, New Mexico, as announced by the U.S. Air Force, will accelerate the acceptance of solar furnaces for high-temperature industrial work in the U.S.A.

Materials in Automobiles of the Future

(*Concluded from page 460*)

ever, that the savings yet to be made in shell moulding will make the cost so much in favour of the cast crankshaft that it will be ultimately accepted.

Nickel is still in short supply, and is quite likely to remain so. Consequently, it is believed that the car of the future will use no nickel in the steels for shafts and gears.

With regard to gas turbines, those so far built have used much alloy to avoid any possibility of failure. Thus, for example, one 200-hp gas turbine weighing 700 lb used no less than 76 lb of nickel in its construction. It is obvious that any extended use of such a power plant must involve lower alloy materials. It is reasonable to assume from a study of each part that the same turbine could be made with materials that would perform satisfactory with a total of 7·5 lb of nickel, and ultimately with as little as 4·75 lb, per engine. Heat resistance in sufficient degree will be achieved in most parts with chromium steels or by aluminizing plain carbon steels. The next twenty-five years will also see the invention of new alloys for those turbine parts which need to operate at 1300 to 1700°F.

The free-piston engine, on the other hand, can be built with metals containing no nickel. The structure of the air chamber and compressor housing could be of aluminium alloy for weight reduction, and the pistons could be partly of cast iron and partly of aluminium. to obtain the proper weight for speed control, with cylinder sleeves of steel, heat-treated to high physical properties, and compressed-air chambers and passages formed of low-carbon steel. The turbine would have rotor and stator blades of an alloy containing only chromium and silicon, and the case would be of pearlitic malleable iron.

Analysis of the Temperature Field in a Gas-Turbine Rotor, using a Hydraulic Integrator

By E. I. MOLCHANOV. (From *Teploenergetika*, No. 1, January 1956, pp. 53–57, 10 illustrations.)

Analysis of the temperature field in gas-turbine rotors under non-stationary conditions is of considerable practical importance. In this connection, V. S. Lukyanov has developed a hydraulic integrator consisting of a network of vessels of adjustable capacity and pipes of adjustable resistance to hydraulic flow. The great convenience of this integrator for the calculation of temperature fields is demonstrated in this article.

To explain the operating principle of the Lukyanov hydraulic integrator, the one-dimensional problem of heat flow in a bar of square cross-section will be compared with the analogous hydraulic process. If the bar is divided into sections, the quantity of heat transferred from section k to section $k+1$ in a unit of time is

$$q = \frac{\lambda F}{d_{k,\,k+1}} (T_k - T_{k+1}) + r_{k,\,k+1}(T_k - T_{k+1})$$

where λ is the thermal conductivity of the bar material, F is the cross-sectional area of the bar, and $d_{k,\,k+1}$ is the distance between the centres of the sections k and $k+1$, whilst T_k and T_{k+1} are the corresponding temperatures.

The increment of the heat content of section k of the bar during a unit of time is proportional to its change in temperature, i.e.,

$$\frac{\partial I}{\partial \tau} = c\gamma V_k \frac{\partial T_k}{\partial \tau} = C_k \frac{\partial T_k}{\partial \tau}$$

where c is the specific heat of the bar material, γ is its specific weight, and $C_k = c\gamma V_k$.

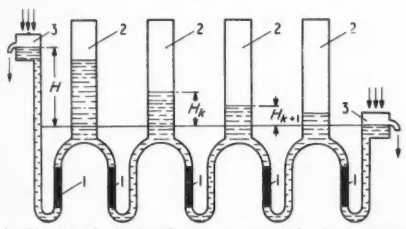


Fig. 1. Diagram of a hydraulic system representing heat propagation in a bar.
(1) Hydraulic resistances ; (2) vessels ; (3) boundary-condition vessels.

Fig. 1 shows diagrammatically the hydraulic circuit, which consists of vessels and hydraulic resistances. If the flow of water through the resistances is laminar, it is associated with pressure by the relation

$$Q = R_{k,\,k+1}(H_k - H_{k+1})$$

where $R_{k,\,k+1}$ is a constant characterizing the hydraulic resistance, and H_k and H_{k+1} are the water levels in the vessels k and $k+1$.

The increment of the quantity of water per unit time is proportional to the rate of change of the water level in vessel k, i.e.,

$$\frac{\partial Q_k}{\partial \tau} = \omega_k \frac{\partial H_k}{\partial \tau}$$

where ω_k is the cross-sectional area of the vessel.

The equations describing the process of heat flow are analogous with those representing the hydraulic process. Thus, if numerical equality of the coefficients $R_{k,\,k+1}$ and $r_{k,\,k+1}$, and C_k and ω_k is ensured, the variations in the levels H_k in the hydraulic circuit will represent, on some definite scale, the temperature variations in the bar under consideration.

Hydraulic integrators, however, are capable of solving much more complicated heat-transfer problems, such as two- and three-dimensional problems, problems involving the formation and absorption of latent heat, and problems concerned with the variation of the physical properties of materials. Moreover, the design of the integrator makes it possible to arrest at any instant the process under investigation, to change the values of the hydraulic resistances and the capacities of the vessels, to prescribe arbitrarily the initial conditions, and to vary, also arbitrarily, the boundary conditions in accordance with any desired law.

Taking as an example a five-stage drum-type turbine rotor such as that in Fig. 4, made of austenitic steel, the coefficients of heat transfer for the different rotor parts are estimated with the aid of approximate formulae. The coefficient of heat transfer to the blades is computed from the relation

$$\mathrm{Nu} = C\,\mathrm{Re}^{0.66}\,\theta^{0.5}\left(\frac{t}{b}\right)^{0.118}$$

The coefficient of heat transfer for the blade roots can then be computed from

$$\alpha_b = \lambda m \tan(ml_b)$$

where $$m = \sqrt{\frac{\alpha_b U_b}{\lambda_b F_b}}$$

In the above equation, U and F are the respective circumference and cross-sectional area of the blade, indicated by the subscript b.

The coefficient of heat transfer from the gas to the cylindrical surface of the rotor can be evaluated from

$$\mathrm{Nu} = 0.023\,\mathrm{Re}^{0.8}\,\mathrm{Pr}^{1/3}$$

From these coefficients a mean value for the coefficient of heat transfer can be estimated in that part of the rotor which is in contact with the gas flow, bearing in mind that the total heat flow is proportional to the surface area occupied by the blade-root cross-sections and the cylindrical surface of the rotor.

The heat-transfer coefficient at the rotor face can be evaluated from the expression

$$\alpha_f = 3w_o^{0.8}\,d^{-0.25}$$

where w_o is the linear velocity at the mean radius of the rotor, and d is the hydraulic diameter, i.e., four times the cross-sectional area of the flow divided by the circumference of the slot.

The coefficient of heat transfer for the rotor sections between bearings and seals can be obtained from

$$\mathrm{Nu} = 0.023\,\mathrm{Re}^{0.8}$$

From this expression, and by considering the configuration of the seals, the coefficient of heat transfer in the seals can be estimated.

As regards the turbine bearings, the Davies criterion may be used in the form :

$$\mathrm{Nu} = 0.0252\,\mathrm{Re}^{0.8}\,\mathrm{Pr}^{0.3}$$

In an actual numerical evaluation of the turbine rotor mentioned above, the following heat-transfer coefficients were obtained :—

Flow passage, α_f = 300 to 900 kcal/m²hr°C
Rotor end faces, α_e = 50 to 150 kcal/m²hr°C
Seals, α_s = 20 to 60 kcal/m²hr°C
Between seals and bearings, α_{sb} = 96 kcal/m²hr°C

Because the coefficient of heat transfer in the turbine bearings is quite large, a constant temperature of 70°C was assumed to obtain at the rotor journals.

At full turbine load, the gas temperature ahead of the first rotor stage is 600°C, whereas behind the last stage it is 407°C. For determining temperatures in the intermediate regions, the temperature is assumed to change linearly. It can further be assumed that the temperature of the sealing medium is the same as that at the rotor end face. The rear sealing medium is air, bled from behind the compressor at a temperature of 164°C. At the front seal there is either gas suction at 578°C or air feed from the compressor, as for the rear seal.

The specific weight of the rotor material is 7960 kg/m³. The specific heat c varies from 0·12 to 0·135 kcal/kg°C, and the thermal conductivity λ from 16·48 to 23·15 kcal/m hr°C, for a temperature range from 20 to 600°C. For the purpose of this analysis, however, it is permissible to use constant average values for c and λ, because their variation with temperature has but little effect on the results obtained.

Since the use of the hydraulic integrator requires the substitution of the temperature field under investigation by a network containing discrete hydraulic quantities, the rotor is subdivided into 34 sections, as shown in Fig. 2. In this connection, it is assumed that the heat capacity of each section is concentrated at its centre, and that the resistance to heat flow between adjacent sections is determined by the distances between their centres. Since the temperature field under investigation has an axis of symmetry which coincides with the rotor axis, the problem is two-dimensional, i.e., the temperature is a function of the radius and one co-ordinate along the axis only.

To set up the equivalent hydraulic system, the following quantities must therefore be evaluated :—

The resistances to heat flow in a radial direction between the surrounding medium and the centres of the outside sections are determined from

$$R_{oi} = \frac{1}{\alpha F_e} + \frac{r_i - r_{i+1}}{2\lambda F_m'}$$

where r_i and r_{i+1} are the outside and inside radii of the section, F_e is the outside surface area of the section, and F_m' is the mean surface of the section between its centre and the outside surface.

Resistance to axial heat flow between the surrounding medium

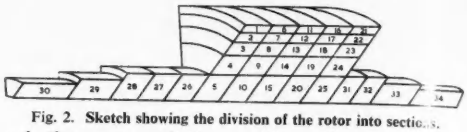


Fig. 2. Sketch showing the division of the rotor into sections.

and the centre of the outside section is given by

$$R_{oi}' = \frac{1}{\alpha F_e'} \quad \frac{l_i}{2\lambda F_e'}$$

where l_i is the length of the section and F_e' its face area.

The resistance to radial heat flow between adjacent sections inside the solid body can be calculated from

$$R_{i,\,i+1} = \frac{r_{i+1} - r_{i+2}}{2\lambda F_m}$$

where F_m is the mean cross-sectional area between the centres of adjacent sections.

The resistance to axial heat flow between the centres of adjacent sections inside the solid body is given by

$$R_{i,\,i+5} = \frac{l_i + l_{i+5}}{2\lambda F_e'}$$

It should be noted that, if areas F_e' of neighbouring sections are unequal, arithmetic mean values are used.

The heat capacity of the section is determined from

$$C = Vc\gamma$$

where V is the volume of the section.

One of the main advantages of the hydraulic integrator is the possibility of selecting an arbitrary time scale, i.e., the time interval during which the thermal process under investigation takes place. The time scale m is determined from the relation between the thermal quantities and their hydraulic counterparts and is given by

$$m = RC/(\rho\omega)$$

where ρ is the hydraulic resistance, and ω is the cross-sectional area of the vessel in the hydraulic integrator. Thus, the required time scale having been selected, the hydraulic resistances and the cross-sectional areas of the vessels, corresponding to the resistances to heat flow and to the heat capacities of the respective sections, can be computed. Once this is done, the pattern of rotor sections is replaced by an appropriate hydraulic system, as shown in Fig. 3.

In the hydraulic integrator, each temperature of the heat-transfer process is expressed by the water pressure in the corresponding vessel. The boundary conditions are given by the pressures in the corresponding boundary vessels and are proportional to the temperatures of the

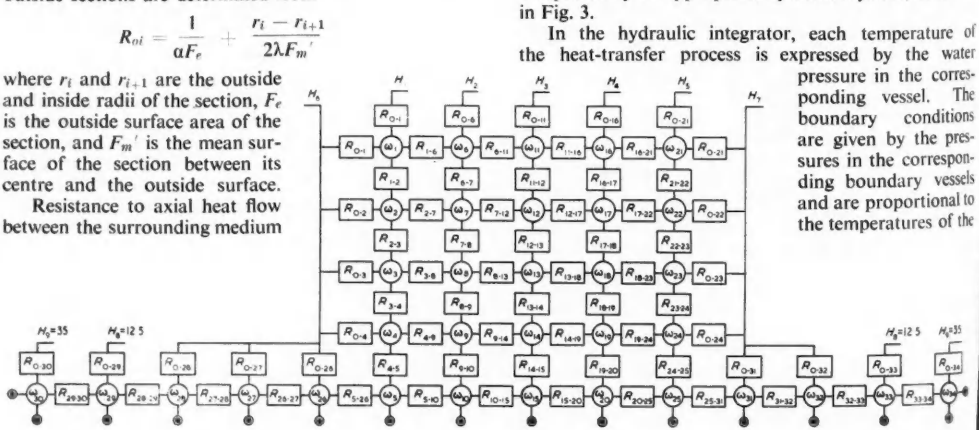


Fig. 3. Diagram of the hydraulic network.

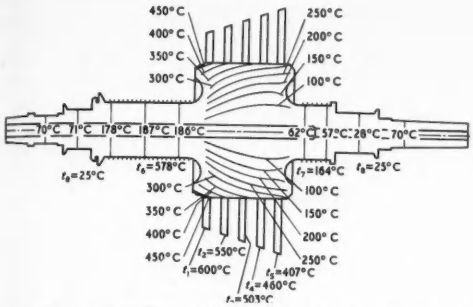


Fig. 4. **Isothermals in the gas-turbine rotor when the temperature drop across a radius is at a maximum.**

$\alpha_f = 900$; $\alpha_e = 150$; $\alpha_s = 60$ kcal/m²hr°C ; the temperature of the front sealing medium $t_6 = 578$°C.

surrounding media. The external resistances to heat flow are represented by hydraulic resistances, computed from the formulae given earlier.

The pressure scale n, the time scale m, and the capacity scale e can be chosen arbitrarily, but the following conditions must be fulfilled to preserve model similarity :—

The pressure/process-temperature relation is

$$H = t/n$$

The time relation between the integrator and the actual thermal process is

$$\tau' = \tau/m$$

The relation of the surface area of the vessel and the heat capacity of the section is

$$\omega = C/e$$

The hydraulic resistance ρ and the water flow Q will then be related to the resistance to heat flow R and the heat flow q by the equations

$$\rho = eR/m \; ; \; Q = mq/(ne)$$

Before starting with actual computation work, the pipes and vessels of the integrator must be calibrated.

Figs. 4 to 6 show the results of an analysis of a gas-turbine rotor, carried out with the aid of a hydraulic integrator. Isothermals at the instant of maximum

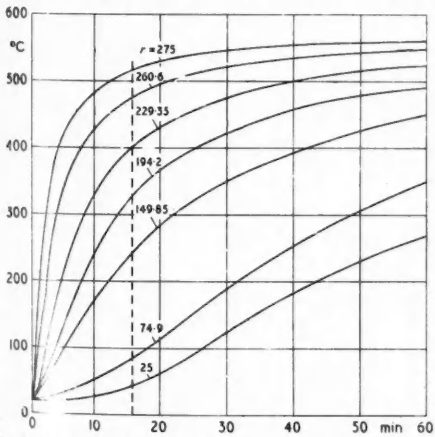


Fig. 5. Temperature variation plotted against heating-up time in the first-stage rotor section for various rotor radii. Boundary conditions as for Fig. 4.

TABLE I

Curve No.	Heat-transfer coefficients [kcal/m²hr°C]			Temperature of front-seal medium [°C]
	α_f	α_e	α_s	
1	900	150	60	578
2	900	50	20	578
3	900	50	20	164
4	900	150	60	164
5	300	50	20	578
6	300	50	60	578
7	300	150	60	578
8	300	50	20	164
9	300	150	60	164

temperature gradient across a radius of the rotor drum are plotted in Fig. 4. These isothermals correspond to the boundary conditions which are obtained from the introduction into the calculations of the higher values for heat-transfer coefficients and from the assumption that gas is being sucked through the front seal during the heating-up period of the rotor. In Fig. 5, temperature changes are plotted against heating-up time for different radii of the first-stage rotor section. The boundary conditions are the same as those appertaining to Fig. 4. The broken line corresponds to the instant of time when the temperature gradient in the rotor is at a maximum.

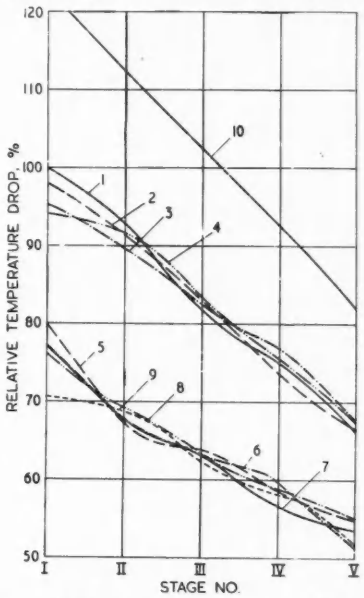


Fig. 6. **Comparison of maximum radial temperature gradients along the rotor axis.**

Curves (1) to (9) correspond to the boundary conditions given in Table I. The gas temperature variation is indicated by curve (10).

Curves of maximum temperature gradient across different radii of the rotor body, corresponding to stages I to V, are plotted in Fig. 6 for various boundary conditions, particulars of which are given in Table I. In the construction of this graph the maximum temperature drop across the first-stage rotor section, the absolute value of which, as can be seen from Fig. 5, is 472°C, has been taken as 100%. The variation of gas temperature in the flow portion of the turbine, at full load, is indicated by curve (10).

(Concluded on page 474)

SWITZERLAND

The Control of D.C. Multi-Motor Drives for Textile Machines by Magnetic Amplifiers

By A. WIEDEMEIER and O. KOLB. (From *The Brown Boveri Review*, Vol. 43, No. 7, July 1956, pp. 260–265, 6 illustrations.)

The particular feature of the multi-motor drive described in this article, which primarily considers the conditions arising in textile sizing machines, is that two of the motors, whose speeds are mutually co-ordinated, are employed to drive a winder at the delivery end of the machine in such a way that the processed material (i.e., the warp) is wound on at constant tension and speed, without having recourse to special mechanical or optical gauging devices.

ALTHOUGH mechanical, electro-mechanical, and photo-electric control systems exist for winding textiles at constant tension, none has so far proved entirely satisfactory.

It is particularly difficult to regulate the speed and tension in machines for sizing the warp. These machines are generally driven by three-phase squirrel-cage motors in conjunction with mechanical devices which are capable of little more than rough regulation of speed. As a rule, it is necessary to apply the driving power at four points which, in the direction of warp motion, are the squeeze rollers (expressing the size), the feed rollers, the draw rollers prior to the winder, and the warping beam itself. The transmission shaft of the normal type of speed-regulation mechanism (belt and conical pulley, or mechanical and hydraulic variable-speed gears) must therefore be positively connected with the four driving points through mechanical elements. Owing to the distances separating individual drive points, these mechanical transmission media are not only bulky and unwieldy, but are also costly and inclined to be rough in their treatment of the warp.

It is naturally advantageous to be able to drive the various sections of such machines by separate motors, the speeds of which retain their co-ordination during starting, stopping, or normal running, without letting the warp become too taut or too slack, particularly just before the warping beam, and despite the very appreciable differences in speed and mass with which the winder motor is obliged to cope. In this connection, the use of improved mechanical tension regulators and electronic controls has produced good results, but electronic systems have the drawback of requiring skilled maintenance to ensure sufficient reliability. Now, however, the recent progress achieved in the construction of magnetic amplifiers has made it possible to overcome this drawback.

In a modern type of sizing machine, the squeeze rollers, the feed rollers (after the drying chamber), the draw rollers (immediately before the winding arrangement), and the warping beam are each driven by a d.c. motor (1), (2), (3), and (4) respectively, as shown in Fig. 1, the direction of warp motion being indicated by the arrow. The warping beam can be

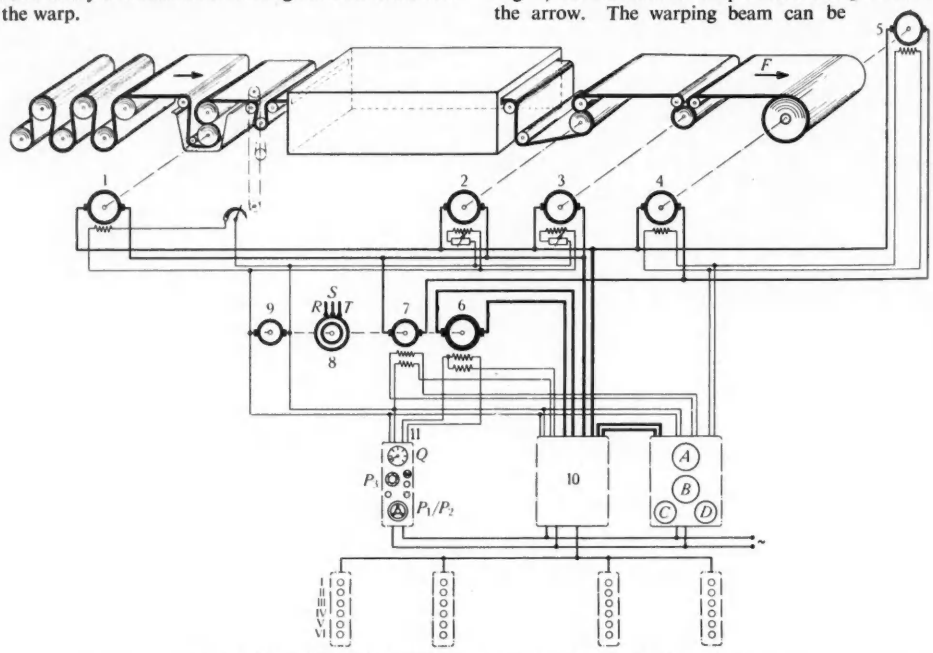


Fig. 1. Schematic layout of a textile machine and winder driven by d.c. motors.

(1) Motor for squeeze rollers.
(2) Motor for feed rollers.
(3) Master motor for draw rollers.
(4), (5) Winder motors.
(6) Ward-Leonard generator.
(7) Booster.
(8) Motor driving converter.
(9) Exciter.
(10) Contactors and control gear.
(11) Control unit.
(*A*), (*B*) Main magnetic amplifiers.
(*C*), (*D*) Auxiliary magnetic amplifiers.
(P_1), (P_2) Warp-speed potentiometers.
(P_3) Tension-setting potentiometer.
(*Q*) Speedometer (m/min).
(I) Start.
(II) Faster.
(III) Slower.
(IV) Creeping.
(V) Stop.
(VI) Off.

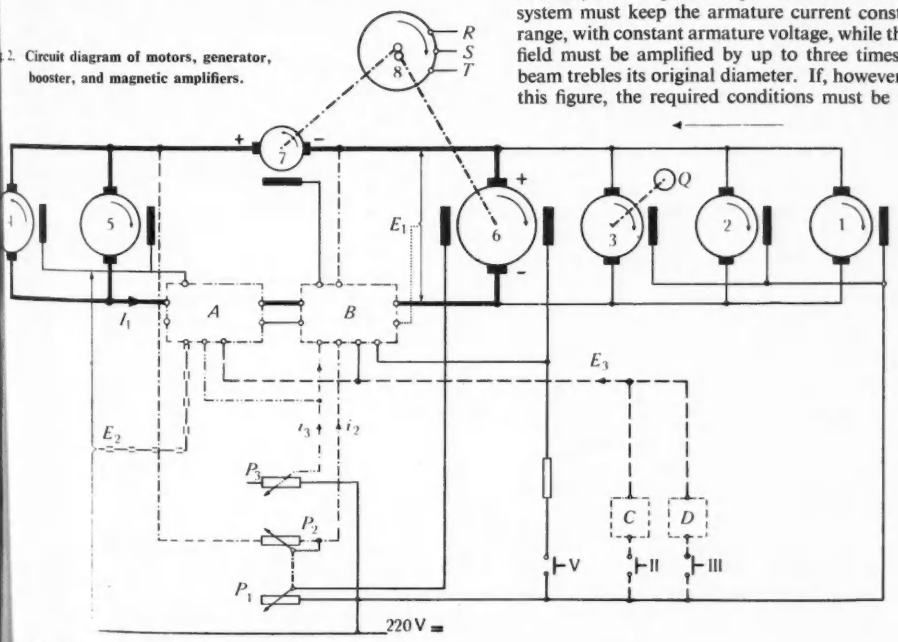
driven by a d.c. motor at each end, so as to avoid torsion, particularly in the case of long beams. A Ward-Leonard generator (6) feeds motors (1) to (5), whose speed range of 1:8 is obtained by varying the generator voltage. The armature circuit of the winder motors (4) and (5) and of the generator (6) also contains a booster (7), the voltage of which can likewise be varied. The purpose of the booster is to raise the speed range of the winder motors (4) and (5) in the ratio of the diameter of the empty beam to that of the full beam, by combined action with a system which varies their fields above the previously mentioned 1:8 speed range of all the motors. This additional speed range was made 1:6 in the drive under consideration. Thus, the winder drive has a resulting stepless speed range of 1:48. Furthermore, the speed of all four or five motors can be reduced by half for a brief interval, to obtain the creeping speed necessary for feeding in or tying broken threads. Hence, the overall speed range of the warping-beam drive is 1:96.

A further purpose served by the booster, during normal running or during acceleration or retardation of the warp, is to control the speed of the winder at all times, so that constant tension is very accurately maintained immediately before the warping beam. The tension must also remain constant if, for any reason, the machine has to be stopped for a brief interval. The magnetic-amplifier regulators (*A*) and (*B*) concerned with the automatic tension control permit this tension to be preselected anywhere within the ratio of 1:10. A mechanical element for measuring either the diameter of the beam or the tension in the warp is therefore superfluous. Mechanisms which make contact with the threads are thus avoided, so that no undesired markings or stripes can result. Magnetic-amplifier regulators react continuously to the change in current and armature voltage of the winder motor, and automatically ensure that the product of current and voltage in the armature remains constant throughout the entire winding process. This product is roughly proportional to the power transmitted to the warping beam by motors (4) and (5), provided that frictional losses in the winding system are relatively low. However, the friction and the losses in the motors themselves can be compensated. The product mentioned above is thus proportional to the product of tension and speed of the warp before the beam, but, since the speed during a run is kept constant, the preset tension in the warp, controlled by the magnetic-amplifier regulator, does not change, even though the beam diameter increases.

The sizing-machine drive described was developed for a machine with a warp-speed range of 10 to 80 m/min, a creeping speed of approximately 5 m/min, a warping-beam speed range at any warp speed between 10 and 80 m/min of 1:6, and an overall beam-speed range of 1:96, beam diameters being 150 mm (empty) and 900 mm (full). The tension F at a 3-hp mean output and at speeds of 27, 40, 60, and 80 m/min was 500, 338, 227, and 170 kg respectively.

At the start of a run, the diameter of the warping beam is, of course, relatively small; during the run, however, it grows until, when the beam is full, it is several times the original size. By keeping constant the warp speed and the power absorbed, which at the same time is the product of the tension F and the warp speed v, then the tension must also remain constant. If it is required to wind at a constant warp speed with a constant tension, the speed of the motors must be inversely proportional to the effective radius r. Since F must remain constant, but r increases steadily, the torque M will also increase, as $F = M/r$. Both conditions can be fulfilled by magnetic amplification at constant armature voltage and current.

With a constant armature current, the torque of the winder motor is proportional to the flux. On the other hand, the speed of the motor is inversely proportional to the flux. To achieve stable running conditions, the field of a d.c. motor may be weakened to only one-third at most, unless special steps are taken. The regulating system must keep the armature current constant in this range, with constant armature voltage, while the magnetic field must be amplified by up to three times, when the beam trebles its original diameter. If, however, it exceeds this figure, the required conditions must be reproduced



2. Circuit diagram of motors, generator, booster, and magnetic amplifiers.

at constant flux. If the armature current at full field is allowed to increase in proportion to the diameter, then the torque will increase in the desired manner. The simultaneous speed reduction is attained by proportionally diminishing the armature voltage as the beam diameter increases.

Fig. 2 shows the basic circuit arrangement and method of operation of the magnetic-amplifier regulator, in conjunction with the winder motors (4) and (5), the booster (7), and the Ward-Leonard generator (6), (8) being the motor driving the converter. The arrow indicates the direction of warp motion. From the circuit diagram it can be seen that the regulating system comprises two main magnetic amplifiers (*A*) and (*B*), of which amplifier (*A*) feeds the feed windings of the d.c. winder motors (4) and (5), while amplifier (*B*) feeds that of the booster (7). As controlling values, the armature current I_1 (actual value) and the opposing current i_3 (set value), which can be adjusted by the tension-setting potentiometer (P_3), affect the magnetic amplifiers, which are both magnetized by current i_3 in one definite direction ; thus, a certain armature current is set at the start of a run. As the diameter of the beam increases, the winder motors (4) and (5) consume more current, so that amplifier (*A*) is magnetized in such a way that its output voltage rises, thus increasing the field of the motors. As a result, the armature current cannot increase further, though there is a slight increase in current from the start until the original diameter has been trebled, owing to the droop of the amplifier.

During this time, amplifier (*B*) must keep the voltage of the booster (7) constant, so that the armature voltage of the motors also remains unchanged. This voltage is preset by means of potentiometer (P_2), which is mechanically coupled to potentiometer (P_1), and at the beginning of the run is equal to the voltage of the Ward-Leonard generator (6), this latter voltage being selected by means of potentiometer (P_1). A rise in armature current causes the output voltage of amplifier (*B*) to drop. Up to three times the original beam diameter, the booster voltage remains practically constant but, as soon as amplifier (*A*) is full out and the armature current can rise, the booster voltage is gradually reduced to zero. The armature voltage of the winder motors (4) and (5) consequently drops by half, while their armature current is doubled and their fields remain at full strength.

So far, the study of this regulating system has been confined to winding at a certain tension and speed ; however, when the speed is changed, the tension must still be kept constant. When the warp speed is increased, there must also be an increase in speed of the d.c. squeeze-roller motor (1), the feed-roller motor (2), the master draw-roller motor (3) with its speedometer (*Q*), and the winder motors (4) and (5), so that it is necessary to step up the output voltage of the Ward-Leonard generator (6) by means of potentiometer (P_1). The voltage of the booster (7) rises correspondingly, since it must, at the start of a run, be equal to that of the Ward-Leonard generator. This is effected by decreasing the reverse-coupling current i_2 by means of potentiometer (P_2).

If the tension must also be changed, the torque of the winding motors (4) and (5) must be varied, while maintaining the same warp speed, by potentiometer (P_3) increasing current i_3. Reducing the resistance of this potentiometer raises the target value of the current in both amplifiers (*A*) and (*B*). Thus, the armature current can rise without amplifying the fields of the winder motors, since the working point of the amplifiers is not displaced. Potentiometer (P_3) can vary the tension in the ratio of 1 : 2, but, by rearranging the connection of the winding carrying the actual value, an additional range of 1 : 4 can be obtained. It is therefore a simple matter to vary the tension within wide limits.

Since the armature current is utilized by the regulating system as a measure of the tension (actual value), the latter can remain constant only if the total output of the winder motors is applied to the beam. In actual fact, there are gears between the motor and the beam, and these consume some of the power. With a weakened field they can cause an appreciable difference in the tension, so that some method of compensating for this difference must be provided. This is effected by means of compensating circuits (E_1) and (E_2).

To keep the tension constant during acceleration or deceleration, two additional magnetic amplifiers (*C*) and (*D*) are included ; amplifier (*C*) functions when the button (II) for " faster " is pressed, while amplifier (*D*) operates when the button (III) for " slower " is pressed. These affect amplifiers (*A*) and (*B*) in such a way that the necessary extra power, with the correct polarity, can be produced (compensating circuit (E_3)).

It is particularly important to keep the tension constant, not only when the machine is running but also when it is stopped. Previously, this was accomplished by means of mechanical devices for preventing backward movement. In the drive described, however, the tension has been maintained purely electrically. For this purpose, when the " stop " button (V) is pressed, the voltage of the Ward-Leonard generator must drop to zero and that of the booster must be reduced until the tension is no more than that when the machine is running.

Analysis of the Temperature Field in a Gas-Turbine Rotor, using a Hydraulic Integrator

(*Concluded from page 471*)

The conclusions reached from an analysis of the results may be summarized as follows :—

(1) During the heating-up period of the rotor, the main heat flow takes place in a radial direction, at least until the maximum temperature drop across the rotor radius has been established.

(2) With a heat-transfer coefficient of 900 kcal/m²hr°C in the flow passage, the maximum temperature drop across a rotor radius is reached 16 minutes after starting the turbine. With a heat-transfer coefficient of 300 kcal/m²hr°C, however, this maximum temperature drop occurs after 25 minutes.

(3) The greatest temperature drop is situated across a radius of the first-stage rotor section, irrespective of the boundary conditions.

(4) Suction of gas through the front seal raises somewhat the temperature level of the rotor body and increases the temperature drop across a first-stage radius, as compared with feeding compressor air to the seal.

(5) When the heat-transfer coefficient in the flow portion is large, even a substantial change in the heat-transfer coefficient at the seals has but little effect on the temperature drop across a radius or on the nature of the isothermals in the rotor body.

(6) If the heat-transfer coefficient in the flow portion is reduced to one-third (300 kcal/m²hr°C), the maximum temperature drop across the first-stage radius is less by from 14 to 30%, depending on the boundary conditions.

The Principle of "Convergence-Divergence" in Mixing and Other Applications

By Dr. M. S. Frenkel*

In this paper, the author discusses his principle of "Convergence-Divergence", which provides a foundation for the solution of a number of problems in different fields, and describes its use as a framework for three basic types of construction, with numerous applications including crushers, mixers, extruders, and dynamic seals.

The principle of "Convergence-Divergence" (*C-D*) may be considered as representing an infinite continuous development of features with effects ranging from convergence to divergence, divergence back to convergence, and so on, this development proceeding on the basis of transfer between a "giver" and a "taker", and a reverse transfer in which a taker is transformed into a giver and *vice versa*. In general, then, each giver must also exert a taker effect, and each taker must exert a giver effect, either in sequence, simultaneously, or in any combination thereof, as illustrated by the three basic constructions described later.

Insofar as convergence and divergence are concerned, convergence is characterized by two features, i.e., (1) similarity, and (2) the process of continuously increasing similarity; divergence, on the other hand, is characterized by the features of (1) difference, and (2) the process of continuous diversification.

As a result, constructions based on the *C-D* principle, which is not rigid, comprise components which are complementary in pairs, each component having a series of continuous variations of configuration between maximum values and zero. Each component thus provides a section or sections having a giver effect, and a section or sections having a taker effect, representing the first feature of convergence between the pair of components. In addition, the series of variations of cross-section of one component faces the reversed series of variations of cross-section from zero to maximum of the other component; thus, the giver effect of one component faces the taker effect of the other, and this represents the first feature of divergence.

This series of continuous variations of configuration for each component of the pair provides a corresponding series of continuous variations of treatment which are complementary to one another. Consequently, material is not subjected to any superfluous or automatically repetitive treatment, but, at the same time, no treatment of the continuous series is omitted.

Owing to the series of continuous variations of cross-section producing the giver and taker effects between the components, the series of continuous variations of treatment is provided, not only by all parts of the operating surfaces of both components but, in addition, a considerable part is provided by the particles of the material itself, as a result of material transfer caused by the giver and taker effects of each component. Moreover, no particles can escape the series of continuous treatment variations.

Another important feature is that, by adjustment of the rotational speeds of the complementary pair of components, or giver and taker sections of such components, the series of treatment variations can be adjusted in accordance with the properties of the material under treatment, both at the intake of the machine and along the entire throughput path. The clearance can also be adjusted, further widening the range of materials which can be treated and their working conditions.

It should be understood that these results can be obtained without constructional alterations and without any particular degree of precision of the configuration of the operating surfaces. Consequently, machines can be made to very wide tolerances, the required results being obtained by subsequent adjustment. Machines constructed on the *C-D* principle, using the three basic constructions to be described, therefore have a wide range of applications, e.g., in continuous mixers, batch mixers, crushers, extruders, kneaders, grinders, and even dynamic seals [1,2,3,4,5], and as many of these applications as required can be combined in one unit. Other applications of the *C-D* principle include its use in a new type of equalizing double angular-contact bearing[7,8,9], and in electronics and control mechanisms[6,11].

In all three basic constructions, each component of the complementary pair has, in accordance with the *C-D* principle, a series of variations of configuration, providing giver and taker effects†. Basic construction I produces in each component of the pair the effects of giver and taker in sequence, while basic construction II provides these effects simultaneously. Basic construction III provides a combination of these effects, i.e., in one part it produces giver and taker effects in sequence, and in the other simultaneously. In other words, basic construction III provides convergence and divergence with each of basic constructions I and II.

It may therefore be said that constructions I and II are the branches of a common root, represented by construction III, and that the latter forms a "framework" for constructions I and II. Similarly, construction III may be considered a framework for other applications based on the *C-D* principle, including its use in turbines and torque converters[3], and in nuclear physics[10].

Basic Construction I

As already mentioned, basic construction I consists of a pair of components providing giver and taker effects in the material-transfer process in sequence. Fig. 1 shows this construction adapted to a crusher, Fig. 1a being a diagrammatic section of the crusher, and Fig. 1b a sectional detail of part of screw section (7) in Fig. 1a. Fig. 1b shows the disposition of the screws after a relative rotation of 90 deg., indicating the action of the threads in sweeping the width of the opposite groove, and of the land (13) of the taker screw (2) in producing the indentation (17) in the material extruded from the inner groove (15). This is due to the approach of the bottom of groove (15) to the tip of the opposite land (13) in the radial direction, (19a) and (19b) being the radial distances for two adjacent grooves. Fig. 1c, which is a section through the grooves of the outer screw (2) in Fig. 1a, shows the thread (13) of the outer screw crossing the thread (12) of the

* Consulting physicist and engineer.

† From the metaphysical point of view, it is analagous to consider that the conscious mind, as a "taker" of stimuli from external surroundings, is itself a "giver" to the subconscious mind up to the commencement of sleep (corresponding to the zero cross-section of the giver screw in Fig. 1). During sleep, corresponding to section (8) (reversed transfer), the conscious mind, which previously was the giver (inner screw in section (7)), now becomes the taker (inner screw in section (8))—not, however, from external sources, but, in the form of a dream, from the subconscious mind (outer screw, sector (8)) as the giver.

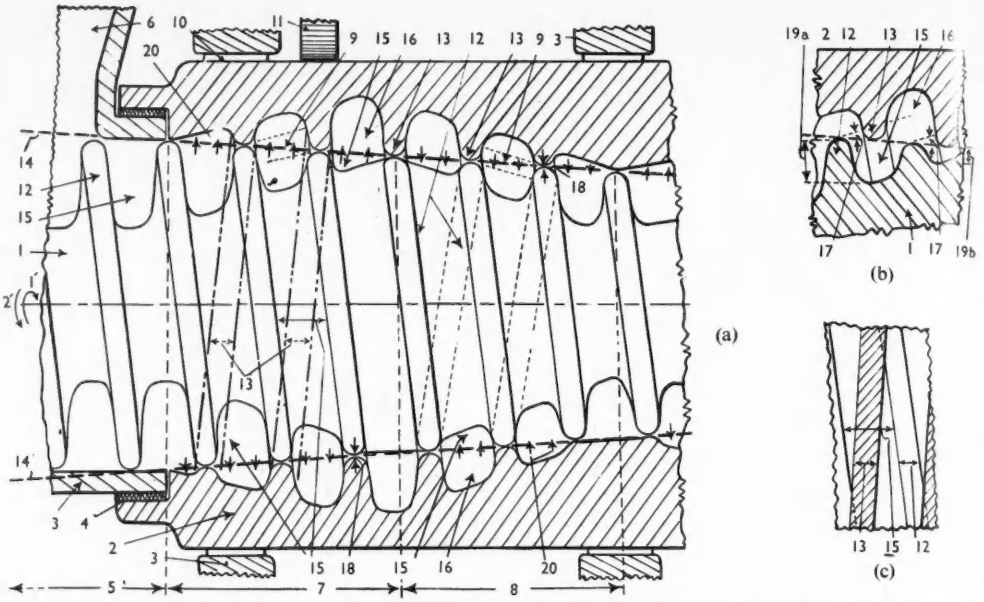


Fig. 1. Basic construction I applied to a crusher, showing (a) diagrammatic section, (b) a sectional detail of part of screw section (7), and (c) a section through the grooves of the outer screw (2).

(1) Inner screw component, with direction of rotation (1').
(2) Outer screw component, with direction of rotation (2').
(3) Fixture.
(4) Seal between casing and outer screw (2).
(5) Feed section of inner screw.
(6) Entry funnel.
(7) Outward material-transfer section of screws.
(8) Inward material-transfer section of screws.
(9) Transition zone between screws.
(10) Bearing for outer-screw component.
(11) Drive for outer-screw component.
(12) Helical thread of inner screw.
(13) Helical thread of outer screw, opposite hand to (12).
(14) Continuously conical interface between tops of threads (lands).
(15) Groove of inner screw.
(16) Groove of outer screw.
(17) Indentations of thread (13) of outer screw.
(18) Clearance between opposite lands of screws.
(19a), (19b) Radial distances between bottom of inner groove and land of outer groove for two adjacent grooves.
(20) Arrows indicating direction of material transfer.

inner screw, and grooves (15). It also shows the sweep of thread (13) across grooves (15) in opposite rotation of opposite-handed screws.

In the outward material-transfer section (7) of the screws, the inner screw has the cross-sectional area of groove (15) reducing from maximum to zero, the outer screw having a complementary increase in the cross-section of groove (16) from zero to maximum. In the inward material-transfer section (8) of the screws, the cross-sectional area of grooves (16) of the outer screw decreases from maximum depth to zero, and the cross-sectional area of the inner-screw grooves (15) increases from zero to maximum depth. Material transfer brings about crushing in different forms, made complementary for all elements of the throughput in one cycle of (7) and (8). In the transition zone (9) between the screws, intense crushing or mixing action takes place. The continuously conical interface (14) between the tops of the threads (lands) permits adjustment of clearance to take up wear, etc., by axial adjustment of the inner screw.

Basic construction I provides the first features of both convergence and divergence, while the second feature of convergence, i.e., a process of increasing similarity, is represented by the variations of the configuration of complementary grooves providing giver and taker effects.

Another aspect of the second feature of convergence and divergence is as follows :—

If it is considered that the complementary series of variations of groove cross-sections along the axis takes place between extreme positions (at the beginning and end of sections (7) and (8)), at which the maximum area of one groove faces the minimum (zero) cross-section of the other groove, it will be seen that, between these extreme positions, there are positions towards which the cross-sectional areas of grooves approach one another. This is a process of increasing similarity, these positions therefore providing what may be called a "region of convergence". On the other hand, beyond this region of convergence, towards both the extreme positions, the divergence of cross-sectional areas of facing grooves increases in opposite senses, i.e., a process of divergence. Consequently, if $f(z)$ and $F(z)$ express the complementary series of variations of cross-sections of grooves with an axial distance z, a region of convergence, of length $2\Delta a$, is provided by the positions in the range between $(z_1+\Delta a)$ and $(z_1-\Delta a)$. Beyond this region of convergence, the functions diverge.

The region of convergence between the positions $(z_1+\Delta a)$ and $(z_1-\Delta a)$ corresponds to the positions of the sleeve in a sleeve travel $2\Delta a$ of a control mechanism[6], because the oscillation effects in all these positions approach stabilization. This property is provided by the author's " stability equations " (a system of differential equations from the first order up to any required order) which, although derived originally for control mechanisms[6], are equally well applicable in these basic constructions and in many other applications, including ball bearings [7,8,9] and electronics [6,11]. In this connection, these stability equations have led to a new oscillatory differential equation for controlled engine systems, completing the conventional oscillatory differential equation which was derived by Maxwell from observation of exist-

ing mechanisms and which has remained unchanged since 1868. This new equation, which is not derived from observation, includes important terms of the same order of magnitude which Maxwell's equation lacks[6,11]. The stability equations themselves are not only not based on existing constructions but, on the contrary, actually serve to derive different classes of mechanisms for various applications. To all these applications the " framework " of stability equations, as a certain combination of functional forms, is common (convergence), while the functions substituted to obtain solutions specify the different applications (divergence).

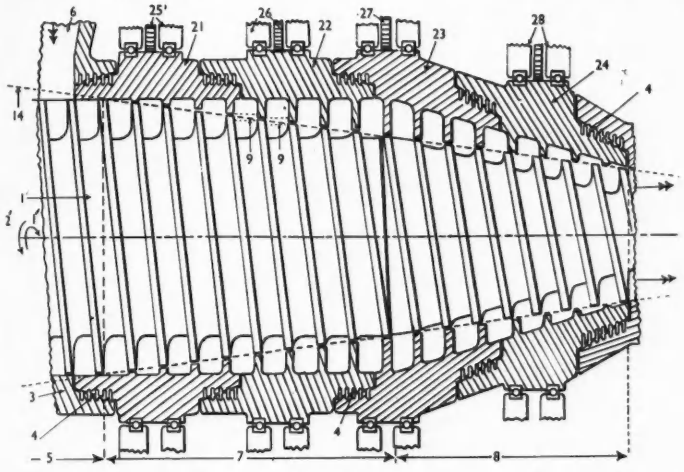


Fig. 2. **Modification of basic construction I for application in a mixer-extruder.**

(21), (22), (23), (24) Sections of outer screw.

(25), (26), (27), (28) Mounting provisions and drives for independent adjustment of rotational speeds of sections.

Other identification numbers as in Fig. 1.

The extremes of convergence and divergence occur at the same positions. Thus, for example, at the end of section (7), where the divergence between the geometrical features is a maximum, the functions of giver and taker vanish, thus providing their greatest similarity (at zero material transfer). In this connection, it should be noted that oscillations in general, e.g., the oscillation of a weight on a vertical tension spring, embody processes of increasing similarity (convergence), followed by processes of diversification (divergence), with positions of extreme values in opposite senses, proceeding in cycles.

A modification of basic construction I, showing its application in a mixer-extruder, is given in Fig. 2, in which the outer screw is divided into four sections (21), (22), (23), and (24), with mounting provisions and drives (25), (26), (27), and (28) for independently adjusting the rotational speeds of these sections, so as to permit control of pressure, etc. along the axis of the machine and hence at the outlet. Incidentally, the seals (4) in this design are dynamic seals (Fig. 3) which are also constructed on the *C-D* principle and which embody the features of basic construction II.

With regard to mixing phenomena, in which the amount of mass intruded from the giver groove into the taker groove operates as a means of mixing the mass content of the taker groove, there are two extreme positions along the axis in each section, as follows :—

(1) At one extreme position, e.g., the last turn of section (7) (Figs. 1 and 2), having groove cross-sections approaching the maximum, the amount of mass intruded into the taker groove from the giver groove, per turn, acting as a means of mixing, meets the maximum taker-groove contents to be mixed. Hence, there is in this case a maximum excess of taker-groove contents being mixed, compared with the amount intruded per turn.

(2) At the other extreme position, in the first turn having minimum cross-sections starting from zero, there is only an intruded mass acting as a means of mixing and meeting practically no taker-groove contents to be mixed. Consequently, in this case there is an opposite extreme, i.e., the excess of intruded mass as a means of mixing, compared with the taker-groove contents being mixed, is a maximum.

Between these two extreme positions along the axis, there is a position, at a distance z_2 from the start, in which the masses being mixed and serving as a means of mixing approach one another. As stated, the region of positions along the axis, from $(z_2 - \Delta a)$ to $(z_2 + \Delta a)$, which form the turn in which this approach takes place, corresponds to the sleeve travel $2\Delta a$ of a control mechanism[6]. Beyond this region of convergence, there are regions of divergence, in which the difference between the amounts of material being mixed and the amounts intruded per turn and forming the means of mixing increases in opposite directions.

The main features relating to three kinds of separation, to various types of intermixing, to multiple driving forces, to self-adjustment, and to control of compression are :—

(a) The elements continuously extruded from the continuously reducing giver grooves are gripped or "clawed" by the oppositely rotating taker grooves and are separated from the giver-groove contents, the size of the fragments depending on the clearance, which is, as already stated, adjustable. This feature caters for the crushing of lumps, the kneading of doughs, the mixing of liquids, etc., corresponding to the state of throughput.

(b) As a result of opposite rotation, the elements separated from the giver-groove contents have impacts with opposite peripheral velocities on the taker-groove contents, producing interpenetration and separation, with a piston (ramming) effect which provides forward drive. Separation with impact also takes place as a result of sudden changes in direction between crossing helices.

(c) Variations of mixing vortices along the axis are caused by the different relative positions of grooves and opposite lands around each circumference (Figs. 1b and 1c), producing different patterns of vortices in the taker grooves around each circumference, depending on whether the intruded material mainly enters to one side, to the other side, or to both sides of the land of the taker groove. As a result, a series of variations is produced, in which one vortex pattern replaces another in the same groove cross-section.

(d) Cohesion of the material and its adhesion to the

walls contribute to the mixing effect, so that sticking of materials in a plastic state is prevented and the forward impelling effects are increased.

(e) As the amounts of material extruded by the giver screw and gathered in by the taker screw are dependent on the rotational speeds of each, the compression, non-compression, or decompression of the material depend on the ratio of these speeds. Thus, a certain speed ratio for each design will provide non-compressive mixing, while a rotating giver groove with a stationary taker groove will produce considerable compression.

(f) Apart from the action of the operating surfaces, an important series of mixing effects is provided by the particles which are being intruded into the taker grooves, thus providing the means of carrying out mixing simultaneously with a continuous increase, from zero to maximum, in the mass being mixed in the taker groove, with corresponding variations in mixing action. This action, in accordance with the *C-D* principle, proceeds in two complementary series, i.e., the first series from zero taker-groove content to a position of equalization between taker-groove content and the mass being extruded per turn and serving as a means of mixing, and the second from this point to the position of maximum taker-groove content. This means, in addition, that the region of positions where the amount of mass being intruded from the giver groove approaches the amount being mixed in the taker groove is a region of convergence, and beyond this region these amounts diverge.

(g) In general, the material transfer from giver to taker causes a piston or ramming effect over the whole of the helical opening of the taker groove, from the position of zero cross-section to that of maximum cross-section. The action is not, however, like that of a rigid piston, but operates as a particle injector, causing interpenetration with impact, thereby promoting the driving force towards the exit, and the crushing, mixing, and other effects on all layers of the throughput, from zero taker-groove depth to maximum depth. This also applies to the giver groove, by virtue of the reaction produced by the ramming effect.

Basic Construction II

In basic construction II use is made of a pair of components having such a series of variations of configurations that giver and taker effects between them are provided simultaneously. Each component of the pair has a similar series of variations of groove cross-section be-

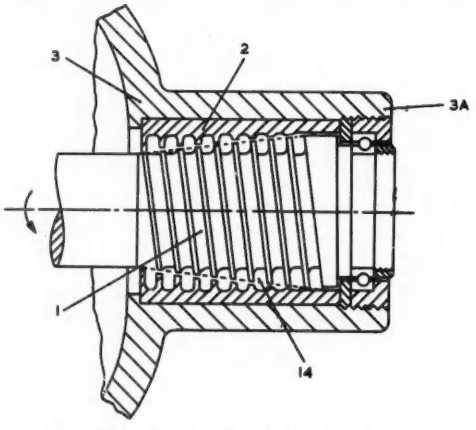


Fig. 3. **Basic construction II applied to a dynamic seal.**

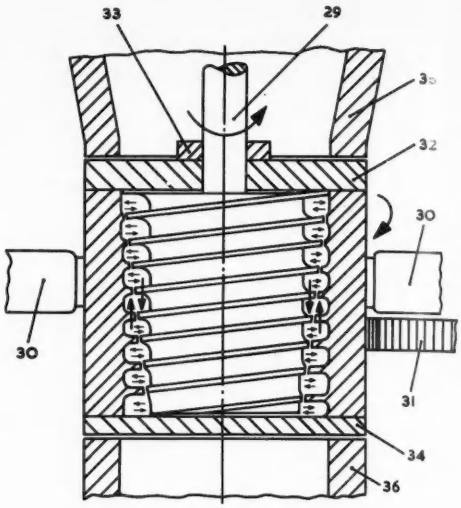


Fig. 4. **Basic construction II applied to a batch mixer.**
(29) Shaft for rotating inner screw.
(30) Bearing for outer screw.
(31) Drive for outer screw.
(32) Top cover of casing, opening for charging.
(33) Gland for drive shaft (30).
(34) Bottom cover of casing, opening for discharge.
(35) Charging funnel.
(36) Discharge chute.

tween maximum and zero, thus providing the first feature of convergence. Since precision is not required, even though all particles are treated, there is a process of increasing similarity, i.e., the second feature of convergence.

With regard to divergence, the series of groove cross-sections is reversed between the two components and, in addition, the two components provide driving forces in opposite directions. Generally, the effect of having the driving forces in opposite directions for each component can be achieved in various ways. Thus, in the example given in Fig. 3, designed as a dynamic seal[5] with the outer component (2) stationary and only the inner component (1) rotated, the external pressure difference between the high-pressure end (3) and the low-pressure end (3A) provides the driving force for the fluid in the stationary screw, and the pumping effect of the rotating screw provides its driving force in the opposite direction. In other types of construction, e.g., Fig. 4, which shows diagrammatically construction II applied to a batch mixer, both screws may be rotated in such a way that their driving forces are in opposite directions. Incidentally, in the design shown in Fig. 4, provision for adjustment of clearance can also be made and, for a wide range of applications, very satisfactory mixing will be obtained with appropriate thread design, even without rotation of the outer casing.

In operation, since the opposite directions of the driving forces of the constructions shown in Figs. 3 and 4 coincide for each component with the direction in which groove cross-sections reduce, the extrusions produced from the screws are in opposite directions, i.e., from the inner to the outer component, and from the outer component to the inner component, each component thus acting as a giver and taker simultaneously.

The mutual and simultaneous extrusion of material from one component to the other provides intermixing with impact in the transit zone all around the circum-

ference, in three mutually perpendicular directions, i.e., in radial directions, owing to opposite extrusions ; in circumferential directions, owing to relative rotations ; and in axial directions, owing to opposite driving forces. As a result, there is provided a much more powerful effect for intermixing and comminution of particles than that obtainable with basic construction I.

With regard to the dynamic seal (Fig. 3), it is a combination of the above effects and others taking place all along and around the interface (14) which provides the necessary sealing action against pressure differences, which can be of any desired amount. As already stated, clearance is not a critical factor and can be taken up by axial adjustment of the screws. Moreover, to prevent possible pumping of fluid, e.g., air, from the low-pressure end (3A) into the casing, two opposed glands of this type may be provided.

Basic Construction III

Basic construction III (Fig. 5) is a combination of constructions I and II, arranged in such a way that, after the feed section (5) of the inner screw, its pair of components has three different sections (7), (8A), and (8B), providing giver and taker effects in sequence and simultaneously. In this construction, section (8) in Figs. 1 and 2 is divided into two parts, i.e., part-sections (8A) and (8B). In part-section (8A), the inner screw reverses the direction of thread (12A), while the thread (13) of the outer screw continues in the same direction. In part-section (8B), the inner thread (12) reverts to its original direction, as in section (7). Thus, while the whole of the outer screw and sections (7) and (8B) of the inner screw impel the material forwards, providing giver and taker effects in sequence, as in basic construction I, section (8A) of the inner screw impels the material backwards, so that in this section the driving forces provided by the outer and inner screws are in opposite directions.

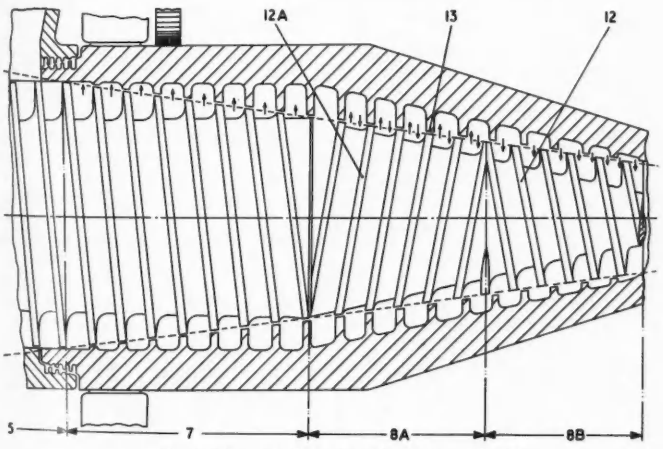


Fig. 5. Diagrammatic section of basic construction III.

Consequently, while in section (8) of basic construction I all the material extruded from the outer screw into the inner screw is driven towards the exit, in part-section (8A) of basic construction III the mass extruded from the outer screw into the inner screw is driven by the inner screw towards section (7). However, this material is prevented from entering section (7) of the inner screw, because in section (7) both screws drive forwards towards the exit, and because of the zero depth of the inner screw between sections (7) and (8A). On the other hand, this material intruded from the outer screw in section (8A) cannot travel towards the exit, because the driving force of the inner screw is away from the exit. As a result, any material which has been intruded into the inner screw is driven along the path of least resistance, i.e., back into the outer screw.

This extrusion of material between the screws provides intermixing and interpenetration with impact around each circumference in three mutually perpendicular directions, as in the case of basic construction II, and provides particularly effective crushing or mixing action. These effects arise from cycles in sequence and from simultaneous cycles.

With regard to cycles in sequence, each particle in part-section (8A) is obliged to pass through a series of cross-sections of the outer-screw groove, corresponding to different axial positions, in which the interpenetration and impact effects occur from a series of different directions. In addition, there is a series of variations of mixing vortices, owing to the series of different relative configurations of opposite grooves and lands in different axial positions. Simultaneous cycles constitute the series of variations of mixing vortices caused by different groove and land configurations occurring simultaneously around each circumference (Figs. 1b and 1c).

It might at first be considered that, since section (8A in Fig. 5, providing simultaneous giver and taker action, extends over only a part of the whole section comprised by part-sections (8A) and (8B), there will be a portion of the throughput not subjected to the simultaneous action described. However, this is not the case because, if the rotations (vortices) in the grooves are taken into account, it will be seen that all particles, even if they do not undergo material transfer with simultaneous giver and taker action, are subjected to the same action, owing to these vortices occurring in the grooves of both the inner and the outer screw[1,2]. Admittedly, this might not be true if the reversed part of the screw in section (8A) had only one turn, but this possibility does not apply in the present instance, where a number of turns is incorporated, with vortices occurring in each turn.

The effectiveness of any desired treatment can be made as high as required in practice by adjusting the rotational speeds of the components, particularly in section (8A), without constructional alterations, because adjustment of the speeds of the screws not only affects material transfer between the components but also the vortices contributing to the intermixing.

The mixed material produced in part-section (8A) is transferred by the outer screw, with its forward driving force, into part-section (8B), whence, owing to the fact that the outer groove reduces to zero cross-section, it is completely extruded into the inner screw, which in part-section (8B) also drives forward and thus transports the mixed material out of the machine. At the outlet end, extrusion nozzles for producing any required cross-

sectional shape may be provided. For other applications, a valve may be fitted for restriction or closure of the exit, either manually operated or operated by the machine itself, so as to provide some particular cycle, e.g., for batch mixing.

This construction, with one stationary component, provides a most effective sealing gland, incorporating provision for preventing any fluid from being sucked in at the low-pressure end. Another useful feature of basic construction III is that, as section (8A) has a reversed screw, axial thrust on the bearings of the inner-screw component is reduced.

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GERMANY

Pneumatic Computing Elements for Automatic Controls

By W. FREDE. (From *Feinwerktechnik*, Vol. 60, No. 9, September 1956, pp. 327–332, 15 illustrations.)

The purpose of this article is to describe the basic features of pneumatic computing elements capable of performing various arithmetical operations in control circuits. They can also be developed to produce exponential and other functions required in practice.

COMPRESSED air, besides being an economical means of energy transfer, is also suitable for the indication and remote control of various physical quantities, such as temperature and displacements, which can be represented by steady or fluctuating air pressures. Pneumatic circuits are being increasingly incorporated in control processes in a number of applications where, not many years ago, electrical equipment was preferred.

BASIC COMPUTING ELEMENTS

Nearly all the arrangements to be described have the common feature of converting the potential or kinetic energy of compressed air into a force which acts on an external member. This force is then compared with other forces obtained by similar or different means in arrangements designed for summation, subtraction, multiplication, division, etc.

Summation :—

Fig. 1 shows a system which can be used for the addition of two pressures p_1 and p_2, which may, of course, represent any physical quantities. The main elements inside the casing are two diaphragms (1) and (1′) made from a flexible material, such as rubber. The two cylindrical bellows (2) and (2′) serve as movable seals with a low spring force (low stiffness). The spaces under the diaphragms are the pressure chambers, with orifices for pressures p_1 and p_2. The spaces above the diaphragms are connected to atmosphere and eliminate reaction forces due to compression or partial vacuum when volumetric changes occur in the pressure chamber.

It is convenient to make all effective diaphragm areas equal, so that $A_1 - A_2' = A_1'$, where A_1 = area of diaphragm (1), A_2' = area of bellows (2′), and A_1' = effective area of diaphragm (1′). The upper bellows (2) bears on a spring (4) of stiffness k and displaces it over a distance δ. The equation of forces is therefore

$$k\delta = p_1(A_1 - A_2') + p_2 A_1' = (p_1 + p_2) A_1'$$

Since the areas and the spring stiffness are constants, the displacement δ is proportional to $(p_1 + p_2)$.

In Fig. 1, the forces are transmitted to the spring (4), and the result is shown by a pointer on a scale (3). However, the output displacement can equally well be transmitted by pick-ups or linkages to other devices in a control system. Furthermore, any number of pressure chambers can, if desired, be arranged in series to summate any number of pressures.

To avoid errors caused by diaphragm forces, etc., the sum of the pressures can be determined by means of a counter-pressure which compensates the forces due to these pressures. This compensation or null-balance method ensures maximum accuracy, and computing elements are usually designed to operate accordingly.

Subtraction :—

A suitable arrangement for subtraction, as used in differential-pressure converters, is shown in Fig. 2, in

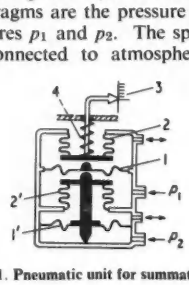

Fig. 1. Pneumatic unit for summation.

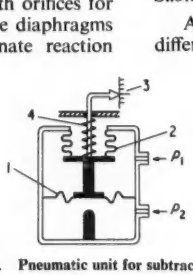

Fig. 2. Pneumatic unit for subtraction.

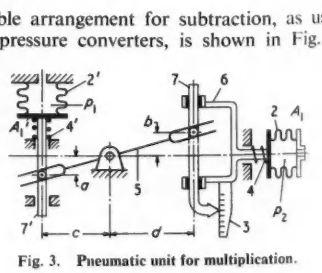

Fig. 3. Pneumatic unit for multiplication.

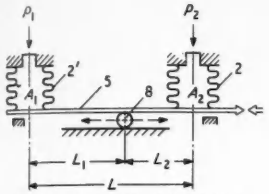

Fig. 4. Pneumatic unit for division.

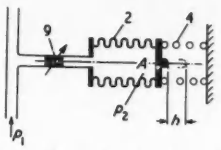

Fig. 5. Pneumatic arrangement for linear and non-linear functions.

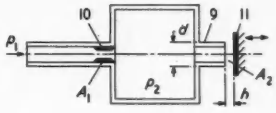

Fig. 6. Pneumatic arrangement for non-linear functions.

which the two pressures p_1 and p_2 act on both surfaces of a diaphragm (1) of area A_1, a cylindrical bellows (2) of area A_2 serving as a movable seal, and the result being shown on a scale (3). Since p_1 can be either greater or smaller than p_2, the spring (4) is designed to be effective in tension and compression. In this arrangement, the effective areas are not equal, i.e., p_1 acts on an area (A_1—A_2), whereas p_2 acts on area A_1. Consequently, the pressures should be chosen so that they will be inversely proportional to the ratio of the effective areas, and this can be achieved simply by using a proportional pressure p_3 instead of p_2. Hence,

$$k\delta = \pm\ p_1(A_1 - A_2) \mp p_3A_1$$

so that δ is proportional to $\pm(p_1 - p_3)$.

Multiplication :—

The multiplication of two pressures p_1 and p_2 can be performed by means of the arrangement shown in Fig. 3. The pressures are exerted inside the cylindrical bellows (2) and (2'), which are coupled together through the slides (7) and (7') and the lever arrangement (5). As the result of pressure p_1, bellows (2') compresses spring (4') and causes slide (7') to move downwards, producing a rotation of lever (5) about its axis. When a pressure p_2 is applied to bellows (2), causing deflection of spring (4), the guide-bracket (6) is displaced horizontally and, since lever (5) remains stationary, slide (7) will move vertically. The only change is that of the distance b, i.e., the height of the pin above the zero position.

From the geometry of the system it can be seen that $a/b = c/d$. If c is constant and the effective areas A_1 and A_1' are equal, then $b = ad(1/c)$, so that b is proportional to p_1/p_2, since a and b are proportional to p_1 and p_2 respectively. The result is indicated by a pointer on a scale (3), or the displacement can be transmitted by mechanical or electrical means to other control devices.

Division :—

Division can be carried out by means of the system shown in Fig. 4, in which the forces due to pressures p_1 and p_2 in the bellows (2') and (2) act directly on lever (5), which is supported by a horizontally movable roller (8). If the areas A_1 and A_2 of the bellows are equal, the mechanics of the system are such that equilibrium is attained when $p_1/p_2 = L_2/L_1 = (L - L_1)/L_1$. This condition is achieved by the displacement of roller (8), so that the value of p_1/p_2 is fully determined by the position of roller (8) when lever (5) is horizontal.

Linear and Non-Linear Relationships :—

An arrangement suitable for the representation of linear and non-linear relationships is shown in Fig. 5, in which a vertical pipe receives a constant pressure p_1 and is connected to a variable throttling device (9), through which air is admitted into the bellows (2), which bears on a spring (4). Depending on the characteristics of the throttle and the volume of the bellows, the relationship between the pressure p_2 in the bellows and time t will follow an exponential law, while the displacement h is also time-dependent. Finally, owing to the stiffness k of spring (4), there is also a linear relation between h and p_2A, i.e., $kh = p_2A$, where A is the effective area of the bellows. Hence, h will reach its maximum value of p_1A/k when p_2 has become equal to p_1. This arrangement offers many possibilities in various applications.

A frequently used arrangement for non-linear functions is that shown in Fig. 6. In this case, a flow of air, at constant pressure p_1, passes through a fixed orifice (10) into a chamber and is then discharged through a variable throttling device comprising an orifice (9) and a pressure plate (11). The pressure p_2 in the chamber is a function of the relative air flows through the two orifices, i.e., it depends on the coefficients of discharge of the orifices, the relative pressures, and the surface area A_1 of orifice (10) and the lateral surface area A_2 of the gap between orifice (9) and the pressure plate (11), respectively. ($A_2 = \pi dh$, where h = air gap and d = orifice diameter. [1,2,3])

With this arrangement, the conversion equation is

$$\frac{\alpha_2 A_2}{\alpha_1 A_1}\sqrt{\frac{p + p_2}{p + p_1}} = \sqrt{\frac{p_1 - p_2}{p_2}}$$

where p is atmospheric pressure and α_1 and α_2 are the respective coefficients of discharge of orifices (10) and (9).

External influences, such as temperature, humidity, and pressure variations of the compressed air and the atmosphere, may affect measurements, and hence the accuracy of the computing operations. The arrangements in Figs. 1 to 4 are not affected by changes in temperature or humidity, since the forces used for computations are determined only by pressures p_1 and p_2. However, pressure changes will have some effect, particularly if they are deviations from a measured characteristic, e.g., a flow/pressure characteristic.

Arrangements incorporating orifices or nozzles involve a possible danger of fouling, with a consequent increase in flow resistance. With the arrangement in Fig. 5, used, for instance, in a feedback circuit, the resistance variation can have an adverse effect on the control system. This effect is much less important with the arrangement in Fig. 6 when a converter or transducer element is employed, since the error is of secondary magnitude in the control process. Influences due to temperature or humidity changes are theoretically also present, owing to the changes they cause in the properties of the compressed air, but in practice they are of little or negligible importance, because disturbances acting on the controller circuit are always compensated.

The above examples show by what extremely simple means it is possible to carry out computing operations with pneumatc circuits, with the degree of accuracy required in practice for control systems.

Examples of Applications

From the wide variety of pneumatic control devices

used in practice, some typical designs will now be considered as examples of the application of the basic arrangements described above.

Fig. 7 shows a control valve (5), with a push-rod and a return-spring (4), which is actuated by the sum of two pressures p_1 and p_2 acting on diaphragms (2) and (1), (3) being a limit-stop. In many instances, it is necessary to split up a controlled quantity, represented by equivalent pressures, into two parts, one of which is used for differentiation (derivative control) or other purposes ; after use, the two components are combined again in a summating valve such as this type, which incorporates the main features indicated in Fig. 1.

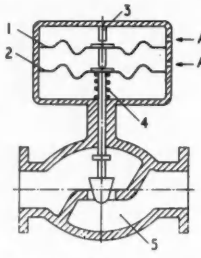

Fig. 7. **Control valve with additive-pressure arrangement.**

A flow indicator and controller is shown in Fig. 8. Devices of this type are employed, for instance, in the chemical industry for the measurement and control of processes from a central position. The upstream and downstream pressures p_1 and p_2 on either side of a standard orifice are applied to a subtracting device of the type considered in Fig. 2. The differential pressure representing the flow is measured in a system including a diaphragm (1), a balance beam (2) with a range adjustment (3), a compensating bellows (4), a discharge nozzle (6), and a hinged pressure plate (5), the result being transmitted to an amplifier (7). The compensating system comprises elements already considered in Figs. 4, 5, and 6 ; the couple acting on the balance beam as a result of the displacement of diaphragm (1) is compensated by an opposing couple produced by means of the lever connected to bellows (4), which receives a compensating pressure (8). In this way, each differential pressure corresponds to a determined output pressure (9). The complete flow controller can be built as a compact unit.

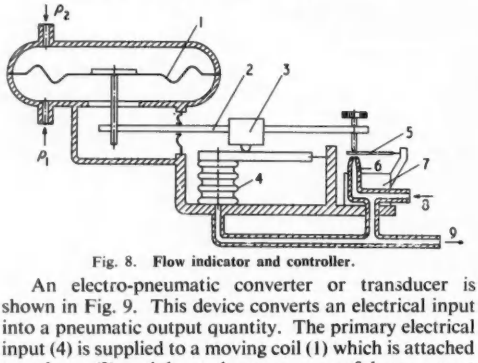

Fig. 8. **Flow indicator and controller.**

An electro-pneumatic converter or transducer is shown in Fig. 9. This device converts an electrical input into a pneumatic output quantity. The primary electrical input (4) is supplied to a moving coil (1) which is attached to a lever (2) and located over a powerful permanent magnet, the coil moving towards or away from the magnet, according to the polarity and magnitude of the input. Air is introduced into the system at (6), and the lever (2) connected to the coil is provided with a pressure

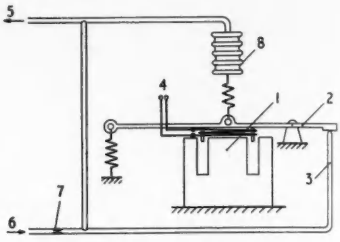

Fig. 9. **Electro-pneumatic transducer.**

plate at its free end, regulating the pressure in the system between the restriction (7) and the discharge nozzle (3). The system is in equilibrium when the restoring couples due to the return spring at the left end of lever (2) and the bellows (8) are equal and opposite to the couple generated by the moving coil. Under this condition, there is complete agreement between electrical and pneumatic quantities. The pneumatic output is transmitted through pipe (5). If desired, a capacitance can be used to smooth out the input voltage.

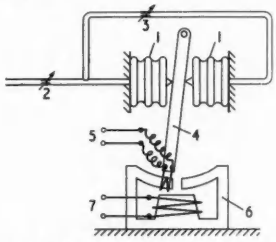

Fig. 10. **Electro-pneumatic feedback unit.**

As a final example of pneumatic control devices incorporating the basic arrangements previously described, it is of interest to consider the electro-pneumatic feedback unit of an electronic controller shown in Fig. 10, the input for feedback being a pneumatic quantity and the feedback output signal electrical. Pressure air is admitted to the two bellows (1) via the variable throttling devices (2) and (3). When a change in pressure occurs ahead of throttle (2), the lever (4) is displaced towards the right or left, depending on the relative adjustment of throttles (2) and (3), returning to its equilibrium position when the pressures before or after throttle (3) become equal. The displacement of lever (4) causes a coil attached to its lower end to move into the left- or right-hand region of the divided magnetic flux of an excitation system (6), fed via (7) with an excitation voltage. Owing to this flux, a voltage is induced in the coil, its value depending on the direction and magnitude of the displacement of lever (4). This voltage is the feedback quantity, which is transmitted to the main controller via the output terminals (5). The complete system also includes a pointer connected to lever (4), to indicate the " trend " of the control process, and a pressure gauge for indicating the inlet pressure, i.e., the manipulated variable.

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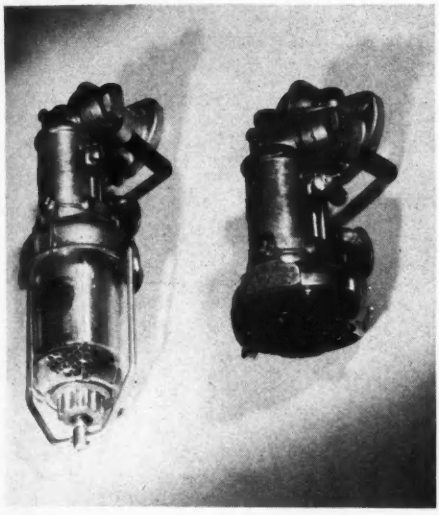
British Industrial Developments

Carburettor with Integral Air Cleaner

A new carburettor, with the air cleaner forming an integral and unobtrusive part of an extremely neat and compact assembly, has been designed by The Villiers Engineering Co. Ltd., of Wolverhampton, and will be fitted initially to their Mark 10 and Mark 12 four-stroke agricultural and industrial engines. Apart from the technical changes which have resulted in improved carburation, an outstanding feature of the new carburettor, designated the B.10, concerns the air filtration.



Two types of filter are available, one an oil-wetted, and the other an oil-bath, model, both having their own adaptors, fitted by two screws to the base of the carburettor. The arrangement forms a complete streamlined assembly, and in consequence both carburettor and filter are far less vulnerable to damage. Furthermore, both types of filter can be removed for routine cleaning and maintenance and refitted simply and quickly without tools.

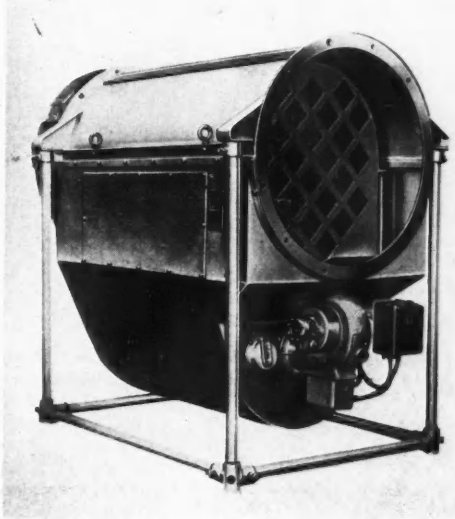
The oil-wetted filter unit (shown on the right of the illustration) consists of a galvanized knitted-wire mesh contained within an open-work plastic moulding. It is secured by two spring clips, and merely requires washing in petrol and immersing in thin oil at regular intervals to ensure satisfactory air cleaning. The oil-bath filter (left), for use in dust-laden atmospheres, has the same location as the oil-wetted unit, attachment to its adaptor being by a strong wire clip and a turnbuckle screw. The cartridge-type filter element is supported within a transparent plastic bowl, which is flexible enough to absorb knocks and prevent breakage. A mark on the moulding indicates the correct level of oil and, as the oil is visible within the container, its condition and quality can always be seen. Removal of the bowl and filter element or cleaning, replenishing, and refitting can also be carried out in a few moments. The danger of the oil being diluted by petrol in the event of flooding is eliminated by the provision of a ledge in the adaptor which diverts the petrol away from the bowl to a porous sintered-bronze drain plug.

The carburettor body comprises two light-alloy castings, the upper portion being common to all sizes of carburettor, and the lower part having bores to suit the capacity of engine to which it is to be fitted. In the upper section of the carburettor a taper screw provides adjustment for the mixture from the pilot jet, a second screw providing slow-running adjustment. The fuel needle-valve assembly is a separate unit which screws into the underside of the body. This enables replacement units, if necessary, to be fitted without difficulty. The normal type of banjo fitting for the petrol pipe incorporates a cylindrical-pattern fuel filter. The lower portion of the carburettor body comprises the float and mixing chambers. The pilot jet is screwed in from the top face, the fixed main jet being located in the side of the casting. A spring-loaded strangler lever and plate are fitted below the venturi. Models fitted to engines running on vaporizing oil are provided with an outlet hole for drainage purposes below the bottom of the float chamber, control being by a drain screw.

Oil-Fired Heat Exchanger

With a wide range of applications in addition to space heating, and eminently suitable for industrial buildings, particularly those with large floor areas, the COB oil-fired heat exchanger announced by Vaporheat Limited, of London, S.W.1, has been designed for connection to ducted systems and to the range of "Aerofoil" fans produced by Woods, of Colchester. The air volume and pressure developed can be arranged to suit almost any application within the range of Aerofoil fan duties, i.e., volumes from 1000 to 55,000 cfm and pressures up to 20 in. water gauge.

The COB "300", which is also an efficient and versatile heating medium for industrial drying processes, is the first of a series, and has a heat output of 300,000 BTU/hr. When equipped with a 30-in. Aerofoil single-stage fan operating at 1440 rpm, it will deliver 8000 cfm, with an air-temperature rise of 34°F, against an external air-system resistance of 0·75 in. w.g. static pressure, or 3·5 in. w.g. with a 30-in. two-stage fan at 1470 rpm.



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Similarly, it will give 2500 cfm, with an air-temperature rise of 98°F, against a system resistance of 5·5 in. w.g., when equipped with a 19-in. two-stage fan at 2850 rpm, fixed by means of a transformation duct section.

The heat-resisting stainless-steel heat-exchanger chamber, giving horizontal discharge, is fitted at each end with drilled fixing flanges of 30 in. i.d. The heat source is a fully automatic pressure-jet oil burner, starting and stopping being controlled thermostatically or by time-clock, etc. Oil consumption is approximately 2¼ Imp. gal/hr, the fuel being gas oil with a viscosity of 35 sec Redwood 1 at 100°F. The heat-exchanger efficiency is 77% to 85%. The unit is supplied complete with an electronic protection relay having photocell flame-failure detection for the oil burner, an air output-temperature control thermostat, a fan and limit control switch, and a special direct-on-line starter with overload protection. The S-type Aerofoil short casing design, as illustrated, is normally fitted where single-stage fans are used. Other sizes under development are 24, 38, and 48 in., to match different Aerofoil fans. The complete range will cover outputs from 175,000 to 1,200,000 BTU/hr.

Continuous Casting of Steel

Mild-steel billets of commercial quality are now being produced in a pilot continuous casting plant at Barrow Steel Works, Limited, at higher casting speeds than have been attained on any other known plant of this kind. The Rossi-Junghans machine at Barrow, on which extensive development work has been carried out over the past three years, is operating at speeds in excess of 200 in. per minute—the equivalent of 7 tons of 2-in. square steel billets per hour.

Carbon and alloy steels for continuous castings are melted down and refined in a 5-ton electric arc furnace. After tapping, the ladle of molten steel is teemed into a tundish at the top of the continuous casting plant, and the steel then flows at a controlled rate into a reciprocating water-cooled copper mould. A partly solidified billet (its central core is still liquid) is withdrawn from the bottom of the mould, and solidification is completed as the billet, preceded by a dummy billet, travels vertically down the machine. When it emerges in solid form, the continuously cast billet is cut to the required lengths.

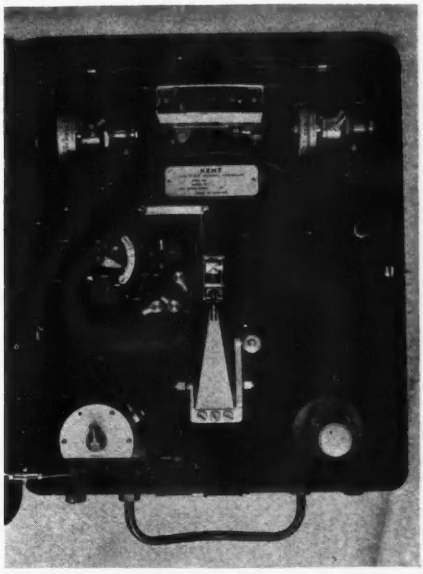
The pilot plant at Barrow is capable of producing billets from 2 in. to 4 in. square, and slabs of up to 6 in. by 2 in. in cross-section. Satisfactory results have been achieved in the continuous casting of mild steels, low-alloy steels, and stainless steel. In subsequent manipulation, the continuously cast carbon steels have been found to have good forging characteristics, while high-quality sheets have been rolled from continuously cast stainless slabs.

Experiments are continuing with a view to establishing a satisfactory process which will be both economic and repetitive.

Slack-Diaphragm-Operated Pressure Controllers

A new range of seven slack-diaphragm-operated pressure controllers is announced by George Kent Ltd., of Luton, Beds. These controllers, designated series FAF, are all of the non-indicating, non-recording, blind-setting type, and comprise suction or pressure controllers, including a special-purpose furnace-pressure controller, differential-pressure controllers, a special-purpose mill controller, and an air-flow controller or differential-pressure transmitter. The general appearance of all these instruments is similar to that shown in the illustration, and all are suitable for wall, panel, or post mounting.

The edgewise gauge at the upper centre of the door shows the "supply" and "control" air pressures of the Kent Mark 20 controlling circuit, expressed as percentages between minimum and maximum range. Any one of a number of mechanisms in the Mark 20 series of pneumatic-controlling units can be fitted in the instruments, covering a number of control terms and facilities. The output signal of the Mark 20 controlling unit varies between 3 and 15 psi. Controlling units employing integral and/or derivative action are provided with control-action adjusting knobs scaled in time units between 0·15 min and 40 min of action time.



The instrument case encloses an air-reducing valve, a relay, and an auto-manual switch. Where special testing and servicing facilities are required for the controlling unit, the instrument is associated with the Kent auto/manual/test/service and remote manual station. Where "overshoot" of the desired pressure value, following a period of regulator saturation, is likely to cause difficulty, and where integral action is used in the controlling unit, an exclusive automatic bleed unit and/or automatic injector unit for insertion in the control circuit is available, connected up as an integral-pressure desaturator, within the instrument case. All these controllers are designed to operate with the diaphragms in the mid-position, corresponding to a 9-psi output of the 3 to 15 psi controlling unit. The desired-value setting of all the controllers can easily be adjusted, and the only maintenance required is the occasional removal of condensation from the filter sump of the controlling unit.

Cast-Steel Shot for Abrasive Cleaning

Cast-steel shot as an abrasive cleaning medium is now being produced on a commercial basis in Great Britain by Tilghman's Limited, of Broadheath, Cheshire, in conjunction with their associate company, Bradley's (Darlaston) Ltd. Designated "Wheelabrator", this shot is manufactured from the finest electric-furnace steel, which is given a double heat treatment to produce a tempered martensite microstructure, resulting in a shot with an exceptional degree of toughness, solidity, uniformity, and operational efficiency.

Extensive tests have established that this shot has an effective life approximately six to eight times that of chilled-iron shot. The average shot consumption per wheel hour was 6·7 lb for steel shot, as against 43·1 lb for crushed chilled-iron shot, in a series of comparative tests. Similarly, it was found that the life of protective wearing

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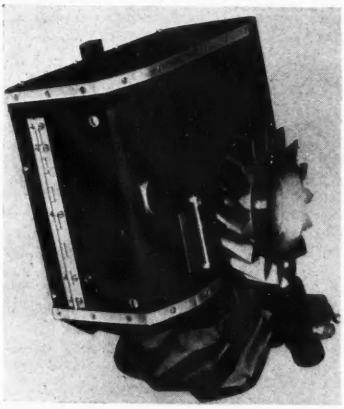
plates coming within the effective area of the shot-blast stream was increased by 56% when steel shot was used, compared with the service period recorded with chilled-iron shot ; moreover, the life of other machine parts, within an area subject to shot ricochet, was increased by as much as 200 to 300% when using steel shot. In addition, blade wear was considerably reduced when steel shot was employed. When using chilled-iron shot, deep grooves were scored in the blade face, whereas blades used with steel shot showed very little wear, even after 103 hours of operation.

The quality of finish obtained by " Wheelabrator " steel shot is more matte in appearance than when using chilled-iron shot, mainly because of the frictional action set up by steel shot at the point of contact. Iron shot, in similar circumstances, breaks down and shatters. The steel shot has greater striking intensity than crushed chilled-iron shot under identical conditions, and actual blast-cleaning time is reduced by between 5 and 10%.

Whilst the original cost of " Wheelabrator " cast-steel shot is higher than that of conventional chilled and heat-treated iron abrasives, this can be offset by the saving in the amount of shot used, by the reduction in blast-cleaning time, by lower expenditure on replacement of wearing parts, by longer periods of productivity without stoppage for servicing, and by reduced maintenance. When all these factors are taken into consideration, a reduction of from 15 to 25% in overall operating costs can be effected.

Helical-Cutter Sharpening Attachment

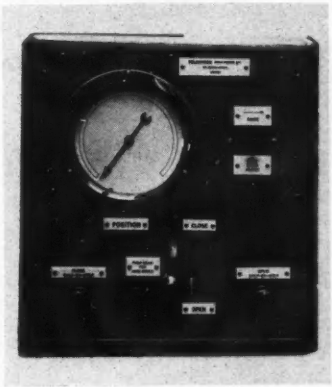
A new model of their helical-cutter sharpening attachment, recently introduced by W. E. Sykes Limited, of Staines, Middlesex, is a development of their standard type SCA attachment, suitable for grinding involute cutting edges on gear-shaper cutters of the Sykes helical and double-helical pattern. The cutting edges of these cutters are in the same or parallel planes—a system which it is necessary to adopt when generating continuous-tooth double-helical gears. This method of sharpening is also recommended for precision gears having high helix angles, and where there is a restriction of the cutter run-out at the end of the operating stroke.



In the new version of this sharpening attachment, all parts of the mechanism are totally enclosed as a protection against grinding dust. Easily opened panels provide access for adjustment and inspection, and moving parts outside the main casing are enclosed in flexible containers. Operating instructions are particularly simple, and the cutters may be sharpened with a near-mechanical routine within a short space of time. After clamping the attachment and the wheel dresser to the grinding-machine table, a vernier graduated in thousandths of an inch is set to half the base-circle diameter, as marked on the reverse of the cutter, alignment of the attachment and dressing of the wheel being carried out according to the detailed instructions supplied. A plunger of the appropriate pitch seats in the tooth space of the cutter, a lever permitting it to be withdrawn for indexing to the next position. To sharpen the tooth, the indexing plunger sub-assembly is swung radially between stops.

Pneumatic Remote-Control Panel for Valves

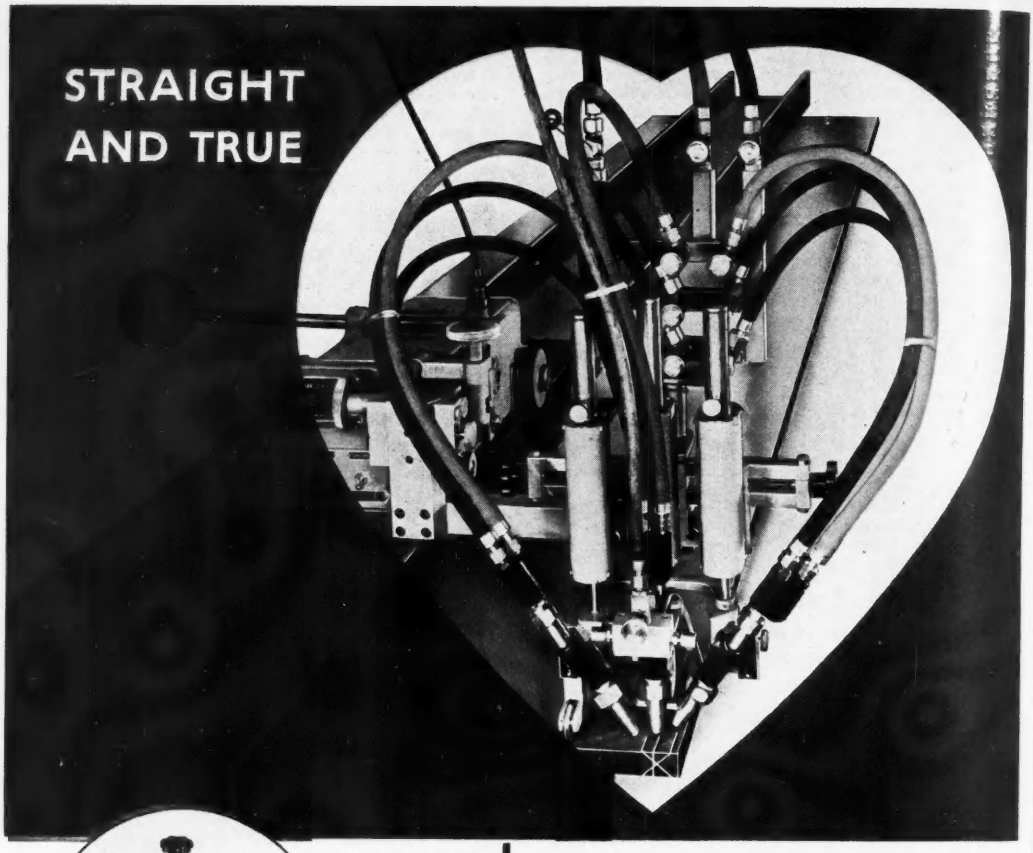
A recent development in valve control, announced by Telektron (Great Britain) Ltd., of London, S.W.1, is the design of a small, compact remote-control panel which provides operators with the same flexibility and sensitivity of valve adjustment as can be achieved by manual control of the valve handwheel. Thus, the panel illustrated provides valve adjustment at both high and low speed, together with step-by-step movement and position indication, a simple standard Telektron motorizing unit being fitted to the valve and connected to this control panel by only four small-bore air lines.

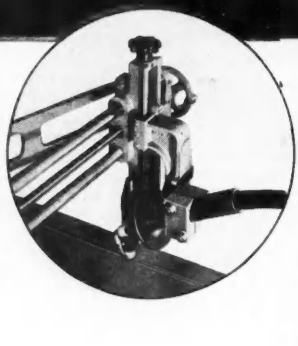


A single valve may be controlled from one or more of these panels arranged in parallel or with a master and secondary panels. The lever-type control provides high- or low-speed operation in either direction, the low speed being adjustable by the operator on the panel face. Push-buttons provide step-by-step adjustment in 36, 58, 76, or 100 positive steps per revolution of the valve handwheel. For each push of the button one step only is taken, no matter how long the button is depressed. A small stainless-steel transmitter unit fitted to the valve transmits position pneumatically to the control station or stations, where it is shown on edgewise or dial-type indicators. An important feature of this position indicator is that its accuracy is unaffected by variations in the air-supply pressure.

An unusual feature of the control panel is the special dual-purpose lever control switch, which has a spring-loaded head, the depression of which in the operational position alters the speed from the adjustable slow speed to full speed. This switch has many other uses in connection with Telektron motorizing units and may be used to provide a single control for interlocked normal or step-by-step operation. For this application movement of the lever in either direction produces a single step, unless the head is depressed in the neutral " Off " position, when movement of the lever in either direction sets the motorizing unit into normal continuous operation. As the head must be depressed from the neutral position, it prevents any danger of accidentally putting the unit into normal operation when a single-step adjustment is required.

STRAIGHT AND TRUE





Above, the SC.5. carrying a three burner floating head for plate edge preparation.

Left, the support arm is shown carrying an argon arc welding torch.

Below, the machine in use as a simple straight cutter with one burner mounted on the support arm. A hand wheel at the end of the arm controls the lead screw which allows minute adjustment of the burner along a traverse of 24".

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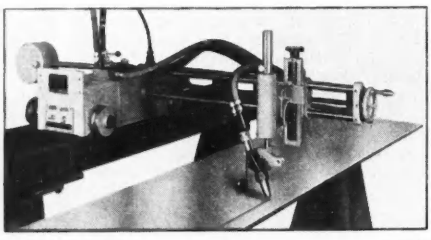

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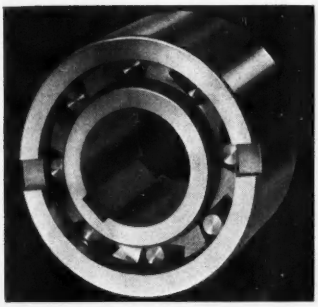
Suitable for incorporation in all types of machinery and with many important applications, a comprehensive range of precision free-wheel units, manufactured in Germany by Stieber Rollkupplung KG, Heidelberg, is announced by Machine Shop Equipment Ltd., of Westminster, London, S.W.1, sole agents in Great Britain. Manufactured to the highest degree of precision, these free-wheel units incorporate a number of special features ensuring long life and outstanding reliability. All parts are hardened and ground, the star wheel has individually sprung clamping rolls and side discs, the outer ring is provided with two slots, and a standard keyway is fitted.



These useful units can be employed as return locks to prevent reverse rotation, e.g., in lifting tackle, conveyor belts, and textile machines of various types, or as safety devices against drive failure or incorrect rotation of drives. They can also be used as control clutches in steplessly variable control and feed installations in presses, planing machines, lathes, grinding machines, packing machinery, textile machines, etc. In addition, they have a wide application for use as overrunning clutches in calenders, rolling mills, printing machinery, blowers, pumps, machine tools, etc. They can also be used for starting steam and other turbines and as a protection against excessive rotational speed. Other applications include the manual operation or setting of turntables, tumbling barrels, etc., and the equalizing of speed differences in rolling mills and in cable-laying and cable-winding machinery.

The standard range comprises fourteen types, with bore diameters ranging from $\frac{3}{8}$ to 5 in., permissible continuous torques from 4 to 6700 lb-ft, and maximum permissible inner-race speeds from 1300, 2300, or 3900 rpm to 160, 300, or 500 rpm, depending on whether grease lubrication, immersion lubrication, or pressure lubrication is used. In addition, special types can also be supplied in larger sizes for higher speeds or for special applications.

Ultrasonic Transducers

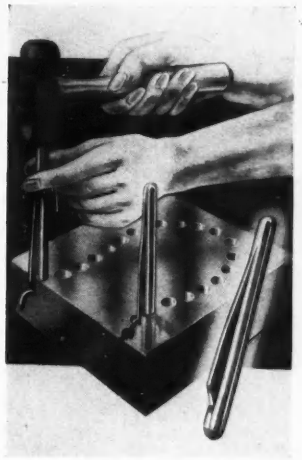
A new range of piezo-electric transducers for wide-spread service in ultrasonic projects is announced by Technical Ceramics Limited, of Towcester, Northants. These transducers are fabricated in ceramic made principally from barium titanate in a polycrystalline form and are impervious to moisture and unaffected by temperature. Furthermore, they are strong, rugged, and able to handle high powers, while their overall characteristics, such as coupling coefficient, dielectric constant, temperature stability, and sensitivity, are generally superior to those found in other transducer materials.

Although certain types and shapes of transducers have been adopted for some specific applications, the flexibility of the manufacturing processes used permits the fabrication of transducers in any desired shape or size. In addition to simple rings, plates, discs, or cylinders, transducer shapes may be combined into dual elements, mosaic arrays, series or parallel systems, and other arrangements to obtain special effects not possible with single elements working alone. Electrodes, consisting of a special silver fused to the ceramic at high temperature, normally cover the whole of the two major surfaces of the transducers, but specific areas can be left bare, if required. The transducers can be supplied with any type of lead; as an alternative, tinned areas can be provided, so that leads can be fitted by the user. In addition, they can be supplied with various protective coatings to suit individual operating conditions. Available coatings include simple waterproofing and a hard plastic coating for moderate cavitation resistance; in cases where corrosion under strong cavitation action has to be prevented, an extremely hard, thin glaze can be applied.

Drifting Tools

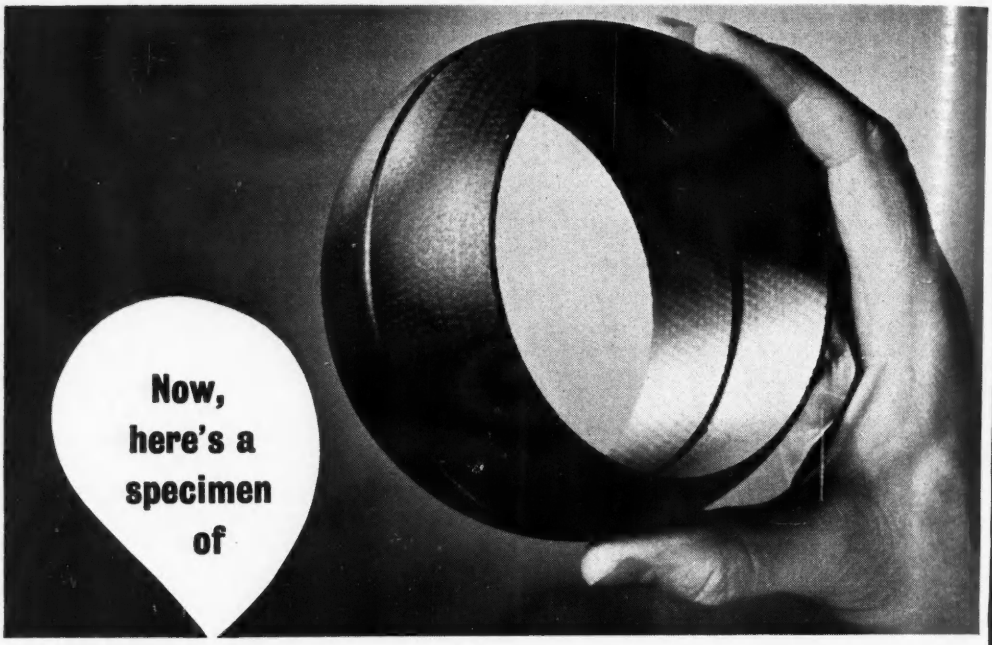
Manufactured in Switzerland, " Holex " drifting tools are now being distributed in Great Britain by Trend Industrial Equipment Ltd., of Stanmore, Middlesex. These tools enable an operator to cut out by hand sections of mild steel, cast iron, or non-ferrous metal, in thicknesses varying from 16-gauge up to 6 in. Merely by hammering the tools into the material (through pilot holes drilled for that purpose), cut-outs can be made by an unskilled operator, dispensing with equipment such as sawing machines and acetylene burners.

The method of applications is as follows :—After marking out the shape of the proposed cut-out, a series of holes is drilled close together along a line marked out for that purpose. The hole diameter should be a little larger (about 0·001 in.) than the diameter of the tool to be used, and the holes should be spaced sufficiently apart, in order to make full use of the projecting edge of the tool.



A few light hammer blows, or the use of a light press, is all that is required to shear away the rib or bridge between the holes.

" Holex " tools, which are made from a special durable hard steel, are supplied in sets of five, different sizes being provided for varying thicknesses and classes of material. The diameters at the base end of the tools range between $\frac{3}{16}$ and $\frac{7}{16}$ in., and lengths between 2½ and 4 in. The general shape of each tool is circular, except for the wedge-shaped and tapered projecting edge, which carried out the drifting operation. They can be used many hundreds of times before a light regrinding of the shearing edge is required. The thickness of the material which can be cut is almost indefinite, as the head of the tools can be punched below the surface of the material.



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CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

BEARINGS

Principles and Applications of Hydrodynamic-Type Gas Bearings.

By G. W. K. FORD, D. M. HARRIS, and D. PANTALL. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, October 26, 1956, 23 pages, 33 illustrations.)

THERE are numerous specialized circumstances in which it may be impracticable to employ bearings lubricated by liquids or greases, and where dry-rubbing bearings are inadequate. In these cases it is sometimes practicable to use a gas to lubricate the bearing system.

There are two basic classes of gas-lubricated bearings of both journal and thrust types, i.e., hydrostatic, and self-acting or hydrodynamic. This paper is mainly concerned with the latter type, which, unlike the hydrostatic bearing, generates its own hydrostatic pressure within the clearance space. by virtue of the viscosity of the fluid in which it is immersed, and because of the relative motion of the bearing elements.

Details are given of an experimental investigation into the properties of hydrodynamic-type gas-lubricated bearings, of both journal and thrust types, as distinct from hydrostatic bearings, together with an account of some developments in their utilization. Two specific developments are described, one being a pump for circulating carbon dioxide gas at 100 psig and 150°C through a loop in a nuclear reactor, and the other a gas-bearing motor driving a pump for molten radioactive bismuth, the whole within a hermetically sealed container. The simple machining requirements and special design principles are also described.

The performance of gas bearings may be predicted from normal liquid-bearing theory, if the loading is so small that the pressure rise within the bearing is a small fraction, e.g., 10%, of the ambient pressure. For higher pressure ratios, compressibility effects must be taken into account. The experimental results and techniques used are reported, those for plain journal bearings embracing a wide range of working conditions and absolute size, including compressible flow operation. An explanation of the physical reasons for the change in performance in compressible flow bearings is given, and the dynamic instability sometimes encountered in journal bearings, together with methods of avoiding it, is also discussed.

CORROSION

The Relation of Thin Films to Corrosion.

By T. N. RHODIN. (From *Corrosion, U.S.A.*, Vol. 12, No. 9, September 1956, pp. 55–65, 15 illustrations.)

COMMERCIAL alloys contain many components which influence their chemical and mechanical properties in a complicated manner. Certain of the alloying constituents are considerably more surface-modifying than others (i.e., they are selectively enriched on the surface when the alloy is exposed to a corrosive environment). In applications where the effects of corrosion are limited essentially to a thin reaction layer at or near the surface, this type of redistribution of the elements between the interior of a metal and its surface can influence markedly the surface properties of the metal.

An approach to understanding the mechanisms of corrosion reactions must provide adequate consideration of the unique properties of these surface films which inevitably result from the exposure of most metals to liquid or gaseous environments. The films reflect their parent metal in many ways. They not only undergo compositional changes but also vary considerably with reference to state of oxidation, compound formation, state of hydration, mechanical continuity, adherence, surface texture, and degree of crystallinity. All these factors characterize the metal surface and reflect the inherent capacity of the metal to mitigate the damaging effects of its environment.

Thin films are sensitively influenced by such factors as alloy composition, corroding medium, and the conditions of exposure. Correlation of these factors with film character provides an insight into the mechanisms of surface reactions. This knowledge, in turn, establishes an effective guide for the development of improved, or, in some cases, new alloy compositions. The film-study approach has been applied successfully to the development of stainless steels with superior corrosion resistance.

The object of this paper is to provide a background on film studies and to describe some specific examples where they have provided a practical basis for achieving improved alloy performance. Evaluation of the resistance to pitting corrosion of silicon-modified Type 316L stainless steel is described as a typical example of an application of a film study to corrosion research. In this case, improved corrosion behaviour was correlated with a mutual film-enrichment of silicon and molybdenum and a film-depletion of iron. Experimental alloys of improved purity were prepared and evaluated. Effects of alloy purity, carbon content, and alloying additions were found to influence strongly surface behaviour and corrosion resistance. The mechanism of resistance to pitting corrosion and the protective nature of the associated oxide films are interpreted in terms of the chemistry of hydrated heteropoly acids containing oxides of silicon and molybdenum.

ELECTRIC GENERATORS

Liquid Cooling of Turbine-Generator Armature Windings.

By C. E. KILBOURNE and C. H. HOLLEY. (From *Power Apparatus and Systems (A.I.E.E.), U.S.A.*, No. 25, August 1956, pp. 646–656, 20 illustrations.)

THIS paper presents an account of the development of liquid cooling for turbine-generator armature windings, including the solution of various detail problems which have arisen in the course of perfecting this cooling method. Using liquid cooling, the heat generated by losses in the armature conductors is removed from the winding by the flow of liquid, either through passages in the conductors themselves or through auxiliary passages built into the winding for this purpose. The need for this, or some similar development, is apparent when the tremendous growth of power systems and their pressing needs for larger generating units are considered.

In this connection, many possible improvements in cooling methods have been studied, and one method using liquid and another using gas have been perfected and are now being applied. Of the two methods, liquid cooling offers greater opportunities for expansion in the kVA-size of the units, while simultaneously retaining design flexibility to meet operating characteristics and maintaining the high level of operating efficiency established by existing machines. For these reasons, much effort has been directed towards its perfection, although liquid cooling is basically not a new idea.

It is concluded that liquid cooling is a practical and effective tool for increasing the outputs attainable from

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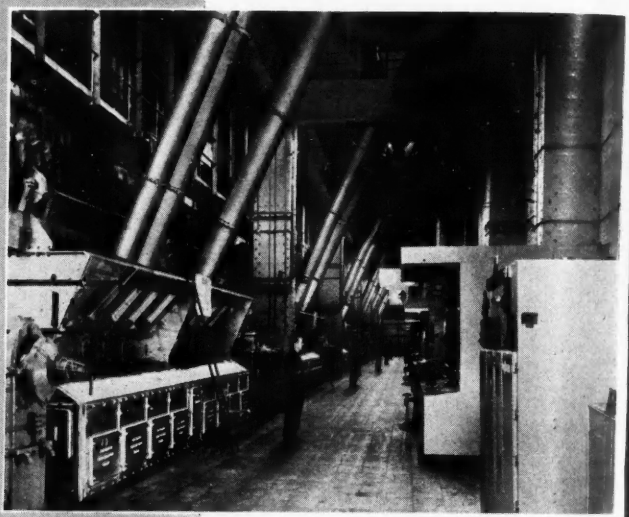
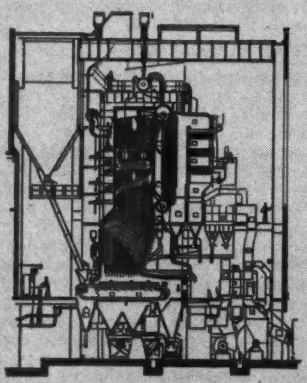
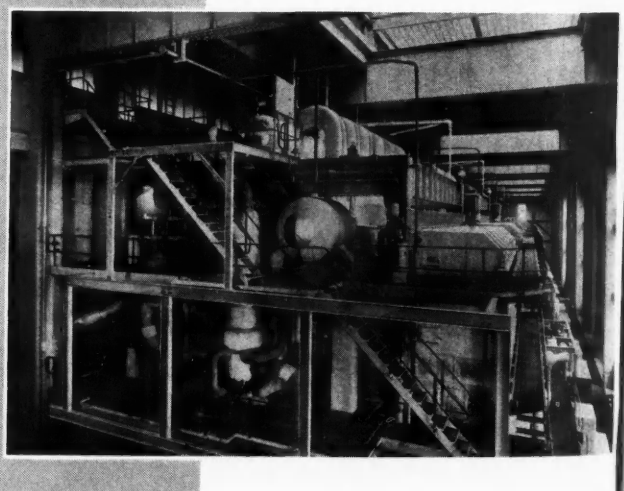
The illustrations here relate to an installation of eleven John Thompson "Radiant Heat" boilers, each producing 180,000 lb./hr. of steam at 630 p.s.i. at the Central Electricity Authority's East Yelland power station. This type of boiler is notable for its high proportion of radiation heating surface. Stokers, ash conveyors and dust extraction equipment at this station are also by John Thompson.

As an example of variation in design to meet differing conditions, other current John Thompson installations for the C.E.A. include 6 "Etaflo" boilers each of 575,000 lb./hr. evaporation at Tilbury and 8 similar boilers at Marchwood—the first new C.E.A. station to go into operation with oil-burning equipment. A feature of the "Etaflo" boiler is its multiple circuits each with definite unidirectional flow—obtaining, by natural circulation, results normally associated with forced flow boilers. The boilers at these stations also incorporate the new patented John Thompson system of super-heat boost, employing non-luminous type oil combustors at the superheater to eliminate the uneconomical dumping of steam on starting up after overnight shutdown.







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turbine-generator armature windings. The liquid-coolant system, now perfected, can be applied readily to all sizes and types of large machines without involving complex design proportioning to accommodate the cooling system. Basically, this is because the cooling ability provided by the liquid-cooled approach establishes a thermal limit for the armature winding much higher than other design limitations in the completed machine. Consequently, with liquid cooling, the thermal design of the armature winding is no longer a limiting factor. The circulating system is extremely simple and very reliable. This step parallels in many respects the step to hydrogen cooling made some twenty years ago, when a more effective heat-absorbing fluid than the air previously used was introduced.

The thermal limit of liquid-cooled windings easily permits the design of armatures for 500,000-kVA rating in 3600-rpm machines, and undoubtedly larger capacities are possible. However, other limitations in the complete machine design are likely to be lower than this figure. Nevertheless, to-day 3600-rpm generators are available in capacities of 400,000 kVA or more at 30-psig hydrogen pressure. Such ratings are practical within the weight and dimension limitations set by rail transportation and by the mechanical limitations of stress and critical speed established by the rotor diameter and length. Even larger-kVA 1800-rpm generators are practical, and the combination of two such generators in a cross-compound turbine-generator unit brings into focus a real possibility of generators feasible for a 1,000,000-kVA unit.

STRENGTH OF MATERIALS

Bending of Plating with Widely Spaced Stiffeners.

By J. C. CHAPMAN and J. E. SLATFORD. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London*, October, 1956, 11 pages, 11 illustrations.)

IT has long been recognized that, where thin plating is acting in conjunction with stiffening members, only a limited width of plating should be taken as being effective. It is usual to assume that the effective width is equal to a certain number of times the plate thickness, and this rule of thumb is required to account for loss of effectiveness due to three quite distinct causes, i.e., (1) distortion of the plating in its own plane; (2) buckling of the plating in compression; and (3) development of a radial component of force, owing to the bending of a plate-stiffener combination in the direction of the stiffeners, causing the plating to deflect out of its original plane, with a consequent redistribution of longitudinal stress and the introduction of a transverse bending stress, which may exceed the longitudinal stress.

Only the third effect is examined in the present paper, which is concerned with stiffened plating to which a bending moment is applied in the plane of the stiffener webs. The effects of initial deflection of the plating and of lateral load are also considered. In addition, a numerical example illustrates the application of the analysis to the transverse bending of a ship's side, and an experiment is described which confirms the theoretical conclusions for an initially flat plate.

The conclusions derived from this investigation are as follows:—

(1) For the example chosen, with a stiffener spacing of 30 in., the effect described has little practical significance unless the stiffeners are initially curved. When they are curved, a considerable local bending stress may develop in the plate at right angles to the stiffeners.

(2) For 60-in. and 100-in. stiffener spacings, there is, in addition to the secondary bending stress, considerable variation of stress across the plate. This variation is accentuated with increasing initial curvature, but is probably not of great practical importance in the example chosen, since the greatest longitudinal stress is in the flange of the stiffener remote from the plate.

(3) Although the maximum stress due to applied bending moment increases with initial stiffener curvature, the bending stress due to lateral pressure decreases with curvature.

(4) For an initially flat plate with two stiffeners, very good agreement has been obtained between theory and experiment.

WELDING

Carbon Migration in Welded Joints at Elevated Temperatures.

By R. J. CHRISTOFFEL and R. M. CURRAN. (From *The Welding Journal, U.S.A.*, Vol. 35, No. 9, September 1956, pp. 457s–468s, 12 illustrations.)

THE diffusion of carbon in steels plays an important part in many metallurgical phenomena. In the case of decarburization, for example, surface atoms of carbon are lost to the furnace atmosphere through their combination with oxygen or hydrogen. Carbon atoms within the metal diffuse to the surface as a result of the concentration gradient thus created. In carburizing, the opposite case is true. In both these instances the carbon diffuses from the higher-carbon concentration to the lower-carbon concentration. If the carbon migration occurring in welded joints behaved in this manner, it would be of no concern, since it would mean relatively slight adjustments in the carbon concentration on both sides of the fusion line, and its effect would be expected to be minor. In instances where a difference in alloy content exists across an interface, such as a weld fusion line, carbon may migrate from one side to the other when no carbon concentration gradient exists, or even in a direction opposite to the carbon-concentration gradient.

If two steels are joined together, a difference in energy is available to provide the driving force to cause the carbon atoms present in one steel to migrate to the other. Thus, the possibility of carbon migration in composite welded joints (welded joints where a difference in alloy content exists between the weld deposit and base metal) is of importance, because carbon can be depleted on one side of the fusion line and concentrated on the other, and can produce a greater effect on properties than a simple elimination of concentration gradients. There is no assurance that the carbon-migration phenomena will have the same time-temperature dependence as normal rupture behaviour, and as a consequence the normal extrapolation of rupture data might be in error.

In order to assess the importance of carbon migration on the reliability of welded joints in high-temperature service, a programme was initiated (1) to determine the propensity of a number of alloy combinations to carbon migration; (2) to develop a time-temperature relationship which would be capable of predicting the extent of carbon migration during service at operating temperatures from short-time tests at higher temperatures; and (3) to determine the properties of welded joints aged to simulate the extent of carbon migration to be expected in service.

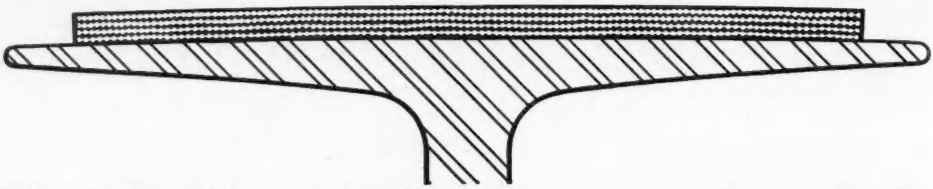
As a result of this investigation, the following conclusions have been drawn:—

(1) Carbon migration in composite weldments can result in a depletion of carbon on one side of the fusion line and a concentration on the other side.

(2) The extent of carbon migration depends on the particular alloy combinations involved and is not strictly a function of the absolute difference in alloy content.

(3) It is possible to derive a parameter relationship establishing the equivalence between time and temperature for carbon migration in composite weldments, and such a relationship was developed.

(4) While physical tests conducted on samples aged to simulate the extent of carbon migration expected in long-time service at elevated temperatures did not show that carbon migration had a profound effect on physical properties, the operation of composite weldments at temperatures at which carbon migration may occur should be carefully evaluated.



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AUTOMATIC MAGNETIC-TAPE CONTROL OF MACHINE TOOLS

A new " numerical control " device for operating complex machine tools by means of digital instructions automatically computed and recorded on magnetic tape has been developed by Electronic Control Systems, Inc., an affiliate of Stromberg-Carlson and a subsidiary of General Dynamics Corporation, of Rochester, New York. Designated " Digimatic ", the new device comprises two main units, i.e., a planning desk, the main part of which is a high-speed decimal computer and a tape recorder, and a machine control unit which governs the operation of a machine tool in accordance with instructions from the magnetic tape. Fig. 1 shows the planning desk, with the high-speed computer on the left and the tape recorder in the desk pedestal. A keyboard for entering dimensional data can be seen on the desk, while the cabinet at the right contains the power supply for all units of the planning desk.

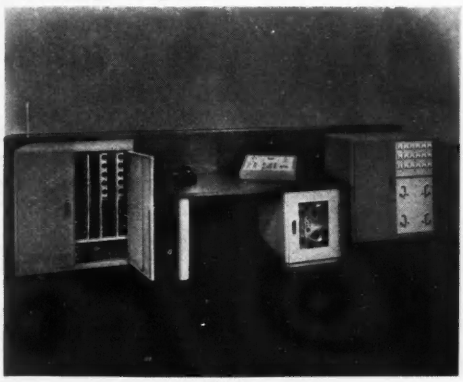

Fig. 1.

In a recent demonstration, a typical precision cam was machined completely from a metal blank, the magnetic tape being used to control all the operations of a vertical milling machine, as shown in Fig. 2, in which the electronic control unit can be seen at the right of the illustration. To prepare for this type of operation, the dimensions of the finished component are first fed into the planning desk in sequence through the special keyboard (Fig. 3). After each dimension is entered into the keyboard, the operator presses a button marked " compute ", causing the computer to take the dimensional data and convert them into the proper numerical instructions, which are simultaneously recorded in pulse form on the magnetic tape. While this computation is in progress (a matter of less than one minute for most dimensions), an indicator lamp lights upon the keyboard, advising the operator to wait before entering further instructions. When the computer is ready for the next dimension, the lamp goes out and a " ready " lamp flashes on. The computer not only converts the dimensional information into the correct number of electrical pulses, but also checks itself, flashing a warning light in case of error. This is effected by counting the number of pulses, making sure that they correspond with the original dimension entered into the keyboard.

One of the important features of the " Digimatic " system is its ability to compute and record the proper instructions for milling true curves. This was demonstrated by producing a number of circles of varying radii on the part machined. Instructions telling the computer whether to produce straight lines or curves and, if the latter, in which direction, are given simply by setting two dials on the keyboard. After all instructions are computed and recorded on the magnetic tape, the latter is rewound and then played back to the machine control unit. A machinist clamps the blank into the fixture and inserts a tool into the spindle, after which servo-motors on the milling machine, in accordance with the recorded instructions, control the movement of the work-table of the machine until the part is completed. During this operation, sensitive transducers check all motions of the machine, ensuring that they correspond with the instructions on the tape. Should the machine deviate in any way from these instructions, the transducers signal the electronic control unit, which produces the proper corrective instruction. At present, the " Digimatic " system is accurate to within 0·001 in., but finer tolerances can be provided, if required.

Among the important advantages claimed for the device, compared with other numerical control devices, are its simplicity of operation and its ease of maintenance. Furthermore, because of its self-checking feature, the pieces produced have an exceptionally high degree of uniformity, rarely matched in ordinary machine-shop operations. In this connection, it should also be remembered that the use of magnetic tape lends itself to the

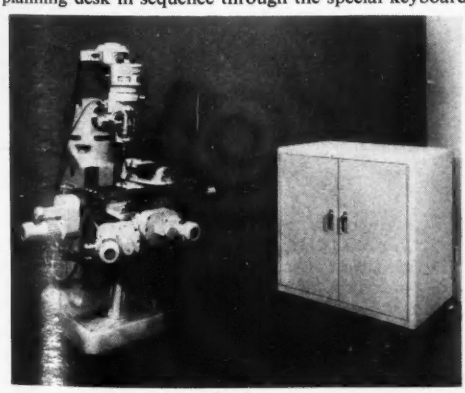

Fig. 2.

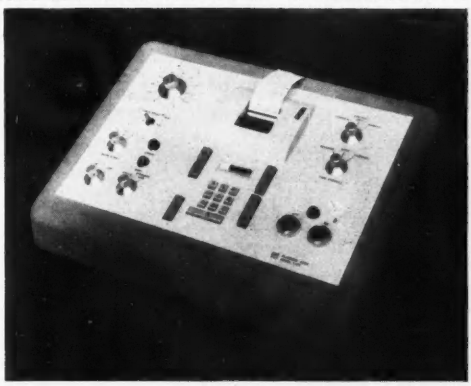

Fig. 3

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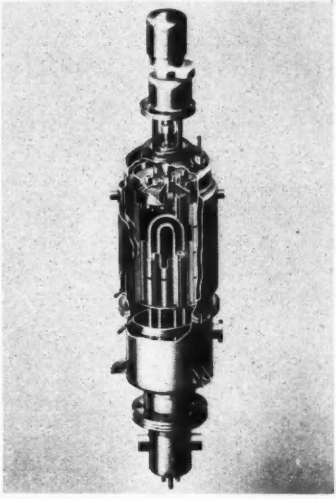
possibility of producing similarly uniform components in other machine shops, no matter how remotely located they may be, merely by the expedient of providing duplicate tapes or by transmitting from an original tape and producing a similar tape at the receiver end. Another advantage of the system is the fact that, since preparation of a tape of recorded instructions in normal machine-shop operations is required only when a new part is to be produced, one " Digimatic " desk can serve as many as five or more machine control units.

FALLING-FILM EVAPORATOR

A new concept in the design of falling-film evaporators is announced by the Pfaudler Co., of Rochester, New York. In this design, the walls of the still are actually contacted by wipers made of impervious graphite or other suitable materials. The wiper design is unique in that the individual wipers are set at an angle so as to direct the flow downwards through the evaporator, as well as circumferentially. By directing the film downwards to the bottom of the still, extremely short contact times are obtained.



In the new design, the wipers are in contact with the heated walls of the still and are held in contact with the walls by centrifugal force. The wipers are contained in a special retainer which allows free radial motion and permits removal and replacement of the wipers without dismantling the entire still. Since the wipers are constructed of short sections, no further compensation for variations in radius are necessary, and the need for internal machining is eliminated. The relation of centrifugal force to rotor speed provides a direct and positive means of producing controlled turbulence in this film-type evaporator.

The use of the carbon wiper has manifold advantages over previous types, including improved heat transfer, short contact time for distillates, constant and uniform film, efficient and economical operation, and reduction in space requirements. Furthermore, this type of floating blade ensures constant contact with the sides of the evaporator, without being affected by changes in dimensions or operating temperatures, and the slow speed at which the still operates eliminates the need for entrainment separators. This new type of construction also permits operation at low pressure drops. At an absolute pressure of 1 mm, the pressure drop can be held to less than 0·1 mm, if desired.

Owing to the simplicity of construction and the inertness of the carbon wiper, a wide range of applications of this type of still is possible. It permits the commercial evaporation of previously impracticable high-boiling liquids, such as wax, fatty acids, lubricating oils, and the purification of plasticizers, concentration of fruit juices, isolation of perfumes and aromatic components, and distillation of petroleum fractions, etc., without the use of steam or other diluents. When used in the molecular range, this distillation equipment permits application in such fields as vitamin recovery from natural triglycerides, dry distillation of glycerin, purification of monoglycerides, isolation of natural oil components, and purification of pharmaceuticals.

At present, the wiped film evaporator is available as a 2-in. glass model and in five diameters of stainless steel, i.e., 12, 24, 36, 48, and 60 in. In addition to stainless steel, the evaporator is also available in monel, hasteloy, nickel, and other workable alloys.

FLUORESCENT FLAW-DETECTION TECHNIQUE

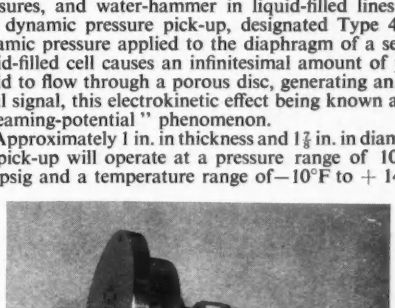
A new technique for detecting minute surface defects in non-magnetizable materials, involving the use of " Britemor " fluorescent flaw-detection " ink ", has been developed by Manchester Oil Refinery Ltd., of Trafford Park, Manchester, and is stated to improve on the older chalk-adhesion test method to a remarkable degree. As a matter of fact, the basis of the new technique is the chalk-adhesion method but, in place of ordinary mineral oil, a special carrier medium is used. This medium is loaded with a blend of fluorescent dyes which, under a suitable ultra-violet light source fitted with a Wood's glass filter, provide a striking and vivid impression of flaw patterns by virtue of the glowing indications produced.

After application of the " ink ", the component under test is rinsed with " Quicmor " wash, washed under cold water, and then dried, either by wiping or with an air blast. The flaw pattern is then developed by dusting with a special dry powder developer, final examination being carried out, as mentioned, under ultra-violet light. Stated to give the most brilliant flaw indications yet achieved, this new simple and certain technique eliminates operator fatigue by enabling even the smallest of surface cracks in non-magnetizable materials to be detected with ease.

DYNAMIC PRESSURE PICK-UP

A new type of pressure pick-up, introduced by the Consolidated Electrodynamics Corporation, of Pasadena, California, measures dynamic pressures, which may consist of complex waves from sonic vibrations, blast pressures, and water-hammer in liquid-filled lines. In this dynamic pressure pick-up, designated Type 4-340, dynamic pressure applied to the diaphragm of a sealed, liquid-filled cell causes an infinitesimal amount of polar liquid to flow through a porous disc, generating an electrical signal, this electrokinetic effect being known as the "streaming-potential " phenomenon.

Approximately 1 in. in thickness and $1\frac{7}{8}$ in. in diameter, the pick-up will operate at a pressure range of 10^{-4} to 100 psig and a temperature range of $-10°F$ to $+ 140°F$,



still undecided?

Indecision is not an uncommon failing. Indeed, many of us in one direction or another will continue to dither, even when faced with indisputable facts.

For instance, it may be perfectly obvious that the tapping screw offers many advantages over the conventional machine screw ; that it eliminates costly thread cutting operations all along the production line ; that it ensures easier assembly ; that for joining metal, wood or plastic, it is stronger, cheaper and faster.

Such facts being recognised and accepted, that the tapping screw makes a stronger, swifter, cheaper, easier, safer and better-looking product — in any material, there seems but one course of action. You're right. Change over to tapping screws ! Still undecided !

LINREAD LTD · COX ST · BIRMINGHAM 3

Linread

SLOTTED AND PHILLIPS RECESSED HEAD MACHINE SCREWS AND TAPPING SCREWS • HIGH TENSILE HEXAGON HEAD BOLTS AND SETSCREWS
AIRCRAFT BOLTS, SCREWS AND RIVETS • SEMS • RIVNUTS • CUSTOM DESIGNED COLD FORGED FASTENERS • ALEX SCREWPLUGS

and has a flat response between 3 and 25,000 cps. Pressure oscillations in this frequency bracket will produce electrical signals which are in phase with and proportional in amplitude to the pressure. This is extremely important, because there will be no phase-lag, or over-shoot of the pressure signals—a common feature of periodic devices.

An outstanding feature of the pick-up is its stability. After temperature cycles, pressure cycles, shock, and vibration, it retains its calibration. Another major feature is its low internal impedance (100,000 ohms), which is much lower than that of piezoelectric-type devices now used in similar work. Furthermore, its output is extremely high. If, for example, a 100-psig oscillating pressure is applied to the pick-up, the open-circuit output will be approximately 35 V. With this high output almost any type of electronic device can be used, provided that proper impedance-matching is achieved. When measuring pressures at varying frequencies, particularly high frequencies, the output of the pick-up may be fed directly into an oscilloscope.

ELECTRONIC CRANKSHAFT-HARDENING PLANT

Claimed to be the simplest and most economical method of processing a few hundred crankshafts per week, a new electronic crankshaft-hardening plant is announced by Radio Heaters Ltd., of Wokingham, Berks.

The hardening unit of the plant (Fig. 1), which is normally powered by the "Radyne" C500 50-kW induction-heating equipment, operating at a frequency of 450 cps, is constructed on a heavy steel frame. A heavy steel tank accommodates a jig plate (Fig. 2), on which are mounted the heating inductors for the particular type of crankshaft being hardened. Different crankshafts are handled by replacement of the complete jig plate and the drawer containing the process timers which fix the heating and quenching cycles for each particular crankshaft. A control panel situated on the front of the unit provides the facilities for automatic or manual operation. Once the crankshafts have been loaded, the heating and quenching cycle is completely automatic. The inductor coils are hinged and connected in parallel. Air rams close each coil in turn, so that R.F. power is fed to only one coil at a time.

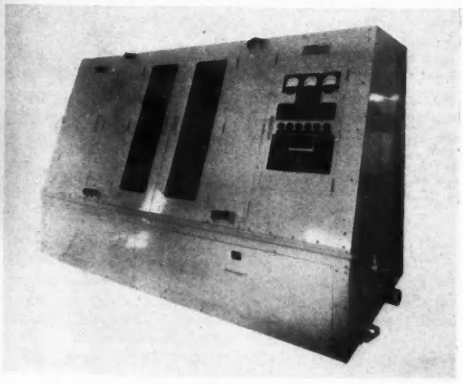


Fig. 1

An automatic switching mechanism enables the heating and quenching cycles to be conducted on different bearings simultaneously. In addition, an automatic re-matching unit enables maximum loading to be maintained on the generator throughout the entire heating cycle, thereby running the plant at the maximum of efficiency. At the end of each heating cycle, water automatically floods over the heated surface, and at the same time the R.F. power is switched to a coil on the other crankshaft. At the conclusion of the whole automatic cycle, one crankshaft is removed and the other moved into its position. A new crankshaft is then placed on the empty jig. In the event of any swarf, etc, shorting out the heating-coil system, the heating cycle will stop automatically and a warning lamp will light, followed by an alarm bell. If it is desired to harden one particular bearing, this may be achieved by switching the plant over to manual operation, when a heating and quenching cycle will be performed only on the one particular bearing to which the selector switch is set.

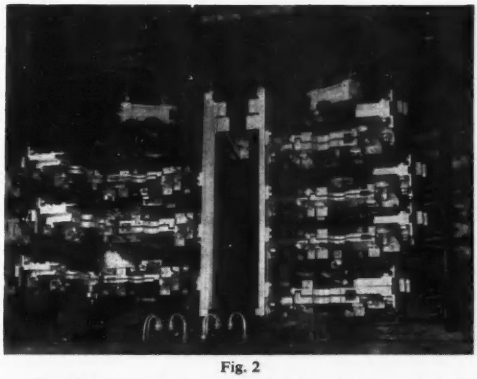


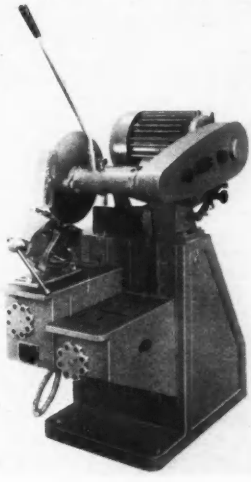
Fig. 2

Jig plates can be supplied for handling crankshafts from 25 to 42 in. in length, of either two- or three-throw. Water requirements are 2 gpm at 60 psi for cooling the R.F. coils, and 10 gpm at 60 psi for quenching the crankshaft bearings.

FOUNDRY ABRASIVE-WHEEL CUT-OFF MACHINE

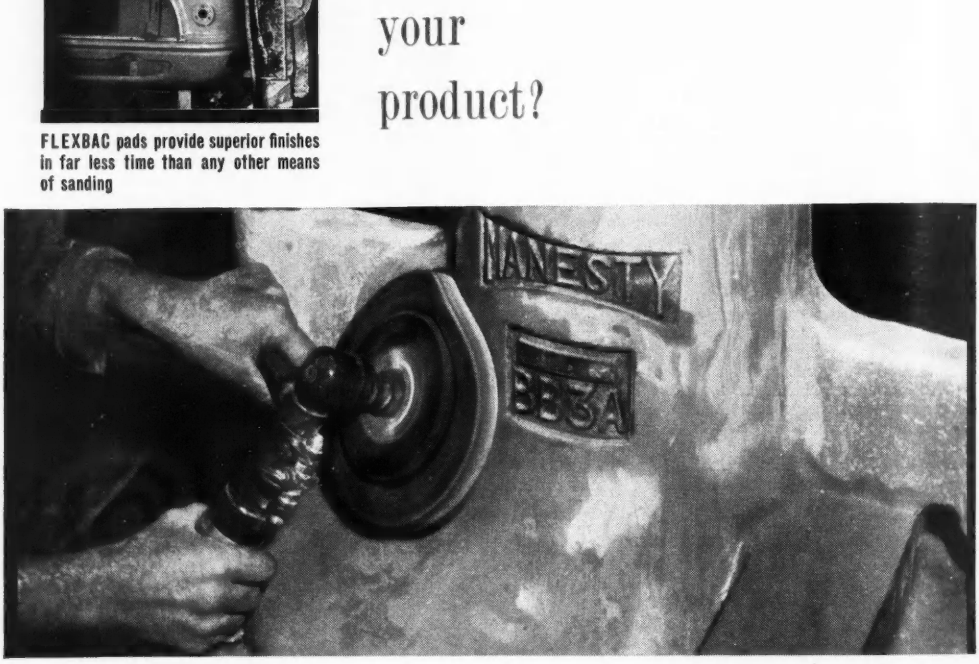
Specially developed for use on medium-sized work in the non-ferrous foundry, a new foundry abrasive-wheel cut-off machine, introduced by A. & S. Osmond Ltd., of Bristol, is announced by the Mortimer Engineering Co., of London, N.W.10. In this new Osmond machine, designated Type "W", cutting is effected by an abrasive disc revolving at a very high speed, and this method should show a considerable saving in time and effort, compared with the method of removing runners by means of a hacksaw.

The machine, which is capable of cutting 2½-in. diameter bronze in approximately 10 sec, is fitted with twin



FLEXBAC pads provide superior finishes in far less time than any other means of sanding

Does finish sell your product?



Concave and convex surfaces, complex curves and plane surfaces . . . all are sanded with greater speed and sureness when a 'Flexbac' pad is used. The supple, foam rubber cushion readily conforms to difficult contours, which would ordinarily need sanding by hand

RAPID DISC CHANGES: When the abrasive is worn, the used disc is peeled off, and a new one pressed into position within seconds. The special adhesive can be re-activated when it begins to lose tackiness.

FLEXBAC PAD

FOR SUPER-SMOOTH FINISHES – FASTER – ON CONVEX, CONCAVE, AND PLANE SURFACES

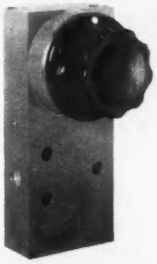
A product by **CARBORUNDUM**

THE CARBORUNDUM COMPANY LIMITED, TRAFFORD PARK, MANCHESTER 17 PHONE: TRAFFORD PARK 2381

cast-iron tables, which are provided with bolt slots to facilitate the attachment of special fixtures. The tables move independently and are counterbalanced; in addition, they can be locked in any desired position by handwheels located in front of the machine. A large vice mounted on a swivel base is also supplied as standard equipment, and is intended for gripping small castings. The rocking frame is fabricated from mild steel and carries a 7½-hp totally enclosed continuously rated motor, controlled via an automatic starter by a conveniently located push-button. The frame can be locked, if desired, to enable work to be fed into the wheel.

PILOT VALVES

A range of 3- and 4-way pilot valves for air, hydraulic, and vacuum operation is announced by the Pneumatics Division of the Baldwin Instrument Company Limited, of Dartford, Kent. These valves, which are unit-constructed and spool-operated, have a standard bore size of ⅛ in. and are suitable for use with air or mineral oils at pressures up to 250 psi. Their primary purpose is to operate remotely located larger control valves which, in turn, operate power cylinders. As a result, the control valves can be located close to the power cylinder, ensuring rapid response. They can, however, also be used for the direct control of small power cylinders, or even larger cylinders if the speed of movement required is relatively low. In addition, they play an important part in the sequential control of machine movements.

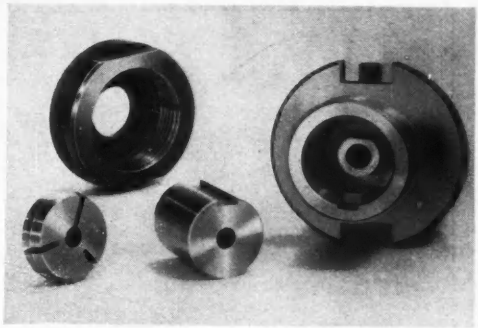


Six standard operating mechanisms are available, i.e., push-button, cam, single-pilot, double-pilot, plunger, and switch. The valve bodies and fittings are of duralumin, anodized to increase resistance to atmospheric corrosion. The spools are of mild steel, precision-ground and hard-chromium-plated, giving a very hard scratch-resistant surface finish which is also proof against water corrosion.

CHUCK WITH ADJUSTABLE CENTRE

A new chuck, the B.S.A. "Tru-Lok" chuck, announced by the Small Tools Division of B.S.A. Tools Ltd, of Sparbrook, Birmingham, is primarily intended for use with milling machines, though it may be readily adapted for drilling and other types of machines where screwed shank tools are used.

Rigidity under the most arduous conditions is an outstanding feature of the new chuck; in fact, under test the heaviest of cuts were employed up to a point where cutters were virtually destroyed, yet the chuck remained perfectly steady and true, and without any evidence of cutter chatter. Another remarkable feature is an adjustable centre, which not only assists in the centralizing of the cutter within the chuck, but also serves to adjust cutter length after a regrind. One of the principal features of the centre is that it can be readily removed from the chuck for its own reconditioning. Moreover, the use of an adjustable centre confers the added advantage that two or more chucks can be set for simultaneous operation, e.g., milling two or more slots to an equal depth to within



the allowable adjustment of the centre. A special centre can be supplied to enable cutters to be adjusted without having to remove the chuck from the machine.

The body of the chuck incorporates a bush which accommodates the screwed shank tool. The bush takes the drive of the chuck through a substantial key, whilst a split collet is provided to take up any variation in shank diameter and, in conjunction with a back centre, centralizes the cutter within the chuck. The closing action of the split collet, effected by a taper seating, eliminates cutter chatter. The illustration shows an end view of the chuck, with the locking nut, collet, and bush removed to expose the driving key and centre.

Two sizes of chuck, each with varying shank sizes, are available. Of these, the smaller size accommodates tools of $\frac{1}{16}$ to $\frac{3}{4}$ in. cutting diameter and is supplied with four bushes and four split collets, while the larger chuck, supplied with three bushes and three split collets, will accommodate tools from $\frac{13}{16}$ to 2 in. cutting diameter.

The Testing of High-Voltage Circuit-Breakers

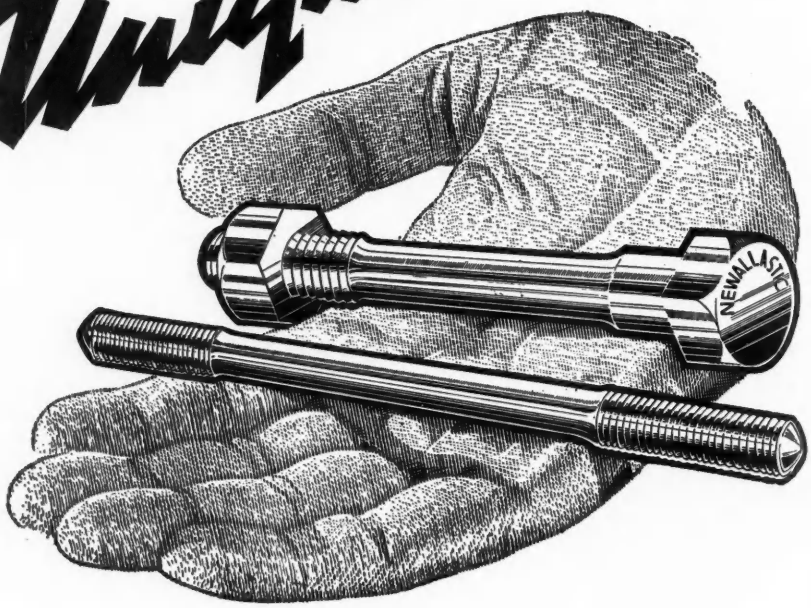
(*Concluded from page 465*)

Interruption of Small Currents:—

When breaking a capacitive load, e.g., the interruption of an unloaded transmission line or a capacitor load, it is not usually possible, if contraction circuit-breakers are used, to avoid restriking. Generally, the result of the restriking phenomenon is not dangerous, chiefly because the high-frequency current which arises during restriking is not interrupted at its first current zero, but at the second, or a later, current zero. As a matter of fact, the direct voltage, if the high-frequency current is broken at the second current zero, will be considerably lower than it was at the commencement of the restriking cycle. Since the most likely result of a series of restrikings will be that the residual direct voltage does not become greater than at the commencement of the restriking cycle, a voltage value is finally obtained, owing to the gradual increasing of the dielectric strength with the movement of the contacts which the breaker can withstand without restriking.

The interruption of small inductive currents can give rise to over-voltages in contraction circuit-breakers in the same way as with air-blast circuit-breakers. However, the switching over-voltages are of less importance at those voltages for which contraction circuit-breakers are used. In certain rare cases, it may, however, be necessary to provide the contraction circuit-breakers with non-linear protective resistors. Tests have been carried out for determining the necessary dimensions of resistors for such cases, and suitable breaking gear for the resistors has been projected.

Unique



"Newallastic" bolts and studs have qualities which are absolutely unique. They have been tested by every known device, and have been proved to be stronger and more resistant to fatigue than bolts or studs made by the usual method.

C. P. Newall & Co., Ltd.

POSSILPARK GLASGOW · N

NEWS OF THE MONTH

PERSONAL

G. V. **Keeling, B.Sc.,** Chairman and Managing Director of Keelavite Rotary Pumps & Motors Limited, Coventry, **F. B. Levetus,** Technical Director, and **N. Lee, B.Sc.,** Technical Manager, are visiting the United States during October and November. The purpose of their visit is twofold; to attend the 12th National Conference on Industrial Hydraulics and to expand the Company's activities in the American market. Mr. Keeling will also attend the Fall meeting of the National Fluid and Power Association.

Mr. E. J. Mansfield has been appointed Works Director and **Mr. E. J. Warren** Sales Director of Edwards High Vacuum Co. Ltd.

Mr. G. G. Roberts, M.Sc., A.F.R.Ae.S. has been appointed to the Board of Smiths Aircraft Instruments Ltd. as Director of Research. Mr. Roberts, joined Smiths two years ago and was put in charge of the company's guided weapons programme. In his new appointment, which took effect on October 9th, he becomes responsible for all guided weapon and aviation research undertaken by the company.

Mr. Charles Frederick Huebner, who has been Chief Buyer for the British Oxygen Company Limited since 1947, has been elected Chairman of the Purchasing Officers' Association.

Sheepbridge Engineering Limited, announce that **Mr. B. C. Goodwin** has been appointed Sales Manager of their subsidiary company Harold Andrews Sheepbridge Limited. Mr. Goodwin was previously Works Manager.

Hardinge Machine Tools Limited, a subsidiary of Sheepbridge Engineering Limited, announce that **Mr. C. J. Calori** has been appointed Sales Director of the Company. Mr. Calori, who is responsible for the Sales of the well-known Hardinge HLV, HC and HCT Lathes, joined the company in November, 1955, as Sales Manager.

Metropolitan-Vickers Electrical Co. Ltd. announces that **Mr. S. Crosbie, A.M.I.E.E., M.I.R.S.E.,** was appointed Assistant Chief Engineer, Railway Signals Department on 1st August, 1956.

British Insulated Callender's Cables Limited announce the appointment of **Mr. K. Collinson, A.M.I.E.E.,** as Branch Manager, Leeds, in succession to Mr. J. R. Tommis, whose death was recently announced.

E. P. Barrus (Concessionaires) Limited of Acton have merged their two sales divisions. **Mr. G. B. Seyman,** formerly Manager of the Tool Division, has been appointed Sales Manager. **Mr. S. M. Whitelock,** who was Manager of the Machine Division is now Assistant Sales Manager. Barrus are sole concessionaires in this country for a number of American products, including Blackhawk Porto-Power Hydraulic Equipment, Duquesne Tyre Service Equipment, Stanley Tools, Johnson Outboard Motors, Devcon Plastic Steel and Cleveland Twist Drills.

The Ministry of Supply announces that **Mr. T. D. Jacobs** has been appointed Director of Instrument Production.

Yarrow & Co. Ltd. announces that **Mr. W. E. Young** has expressed his desire to retire after being with the Company for 46 years and is resigning from the Board of Directors of the parent Company and also from the Board of Yarrow (Africa) (Pty.) Ltd. on the 31st December, 1956.

Mr. A. Knowles, Manager of the Wembley works of British Oxygen Gases Limited, has been appointed Technical Manager, Acetylene, at the Company's headquarters at Bridgewater House. He takes over the position formerly held by **Mr. E. A. Groom,** who is taking up an appointment with the parent organisation, the British Oxygen Company Ltd. The new District Manager at Wembley is **Mr. D. R. Harris,** formerly Assistant Production Manager at the Head Office, British Oxygen Gases. **Mr. Robert J. C. Bryce** has been appointed District Manager of the Scottish Division of British Oxygen Gases Ltd.

Mr. A. H. Cartwright has been appointed to the Board of Vent-Axia Ltd. He has been an Executive Director of the subsidiary company, Axia Fans Ltd. since 1946. **Mr. R. E. Thompson,** Works Manager of Axia Fans Ltd., has been appointed a Director of that company.

Sir Graham Cunningham, chairman and managing director of the Triplex Safety Glass Company Ltd., has been elected Renter Warden of the Glaziers' Company.

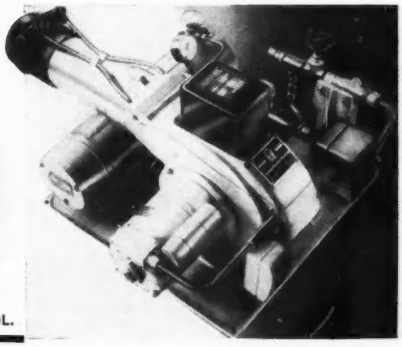
Mr. C. A. French, assistant chief accountant at the Central Electricity Authority's headquarters, has been appointed a Deputy Chief Accountant at headquarters. Mr. French joined the British Electricity Authority at headquarters in 1948 and was appointed Assistant Chief Accountant in 1949.

The new ZH OIL BURNERS

Results achieved by the Nu-way ZH Burners are exceptional. Greater combustion efficiency—maximum reliability. Routine servicing can be carried out by non-technical staff. Three models of from 615,000 B.T.U.s/hr. to 2,140,000 B.T.U.s/hr. Write for literature.

- Nu-way combustion head
- Less refractory required
- Visible flame front
- Constant oil temperature
- Two-stage filtration
- Simple maintenance
- Fine atomisation
- Rapid start on demand

Nu-way
THE LEADING NAME IN OIL-FIRING



NU-WAY HEATING PLANTS LTD. (Box 559) DROITWICH
and at LONDON, MANCHESTER, NEWCASTLE, GLASGOW, BELFAST, DUBLIN, BRISTOL.

Experience

like this . . . speaks for itself

BOILER PLANT	NO. OF UNITS ORDERED	EVAPORATION K lbs/hr M.C.R.	STEAM CONDITIONS		DATE OF COMMISSIONING
			PSI	°F	
Littlebrook 'C'	7	360	975	915	1952-6
Stourport 'B'	1	515	1550	1060	1954
Drakelow 'A'	4	515	1550	1060	1954-5
Connah's Quay	6	300	625	825	1954-7
Portobello	2	540	1400	965	1954-5
Ince	4	550	950	925	1954-7
Skelton Grange 'A'	3	550	975	940	1954-6
South Denes	2	550	950	925	1956
Willington 'A'	3	830	1600	1060	1956-8
Drakelow 'B'	1	860	1600	1010/1005	1957
Agecroft 'B'	2	860	1600	1010/1005	1958
High Marnham	3	1400	2450	1060/1005	1959-60

IC Power Station installations such as these regularly figure in the annual list of the twenty power stations with the highest thermal efficiency. They are evidence of the vast experience gained by IC in the design and construction of outstanding boiler plant, both large and small.

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TGA 5511

Sir William Stanier, one of Britain's most distinguished engineers, will be President of the Engineers' Guild during 1957. Since 1950 Sir William has been Chairman of the Power Jets (Research & Development) Co. Ltd., as well as a director of other companies.

The appointment of **Mr. J. R. Allan, B.Sc. (Eng.), A.M.I.Mech.E.,** as General Manager of the Acme Companies, in which are incorporated Acme Conveyors Ltd., Acme Ventilating Ltd., and Acme Welding & Constructional Engineering Co. Ltd., has just been made.

The Parent Company of the 600 Group recently announced that it had changed its name to The George Cohen 600 Group Limited, and transferred its trading activities to a new wholly-owned subsidiary called George Cohen Sons & Company Limited. In addition to those who are already on the Board of the Holding Company, the following—all of whom have held high executive positions with the Company for many years—have been appointed Directors of the new Subsidiary Company: **Mr. J. A. J. Blanckensee, Mr. D. W. Cooper, Mr. A. S. Gill, Mr. C. E. G. Nye, Mr. J. H. Pawley, Miss E. P. Wood.**

Mr. J. A. Dewhirst and **Mr. P. H. Ogden** have been appointed Local Directors of George Cohen Sons & Company Limited, the newly-formed trading subsidiary of The George Cohen 600 Group Limited. Mr. Dewhirst and Mr. Ogden will continue to operate from their headquarters at the Company's works at Leeds and Sheffield respectively.

Mr. George Teasdale has been appointed London Director of The Villiers Engineering Co. Ltd., manufacturers of two-stroke motor cycle engines, two-stroke and four-stroke agricultural and industrial engines and bicycle freewheels and sprockets, of Marston Road, Wolverhampton, in place of **Mr. Christopher C. C. Bridge** who has found it necessary to resign from the board owing to the mounting pressure of his many other activities.

Mr. Robert Appleby has been appointed Managing Director of Black and Decker Ltd. He succeeds the late Mr. J. V. Franklin. Mr. Appleby will retain his position as director of International Operations of the parent company, Black and Decker Manufacturing Company, Towson, Maryland, U.S., in which capacity he is responsible for all the parent company's activities outside the U.S. and Canada. Mr. Appleby, who is 43, joined Black and Decker in 1953 as a director and later in that year was appointed Director and General Manager.

Mr. James Allen, the chief inspector for George Ellison Ltd., who retired on 31st October, has been responsible for inspection of all equipment leaving the factory for the past 43 years. Mr. Allen is succeeded by **Mr. Frank Mullis.**

In order to handle a rapidly increasing volume of development work due to Esso Petroleum Company's future expansion programme, a new department has been established at the London Head Office, to be known as Development (Operations) Department. **Mr. E. Evans-Jones, M.I.C.E., A.M.I.M.E.,** is to be manager of the new department, **Mr. G. A. Vickers,** manager of Development Engineering, while **Mr. R. L. Hill** becomes manager of Budget Control, and **Mr. J. F. Biden,** manager of Distribution Planning.

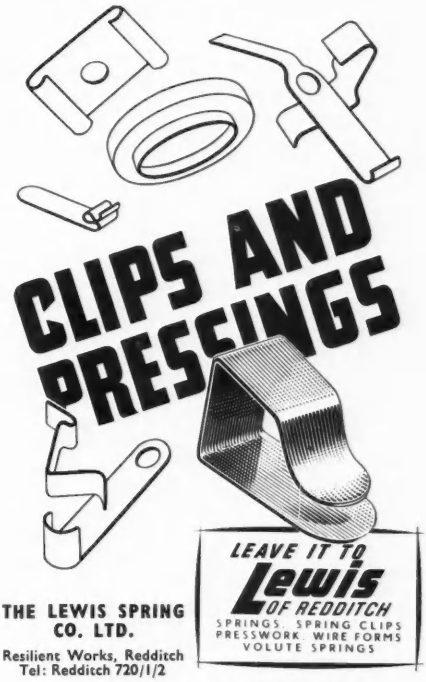
Messrs. T. S. Harrison & Sons Ltd., of Heckmondwike, Yorkshire, have recently been visited by their United States Representative, **Mr. Stanley Sheppard,** who spent two weeks arranging for an increased allocation to meet the growing demand for Harrison Lathes in the U.S.A. Mr. Sheppard represents Messrs. Adcock and Shipley Ltd., of Leicester with whom he also spent some considerable time discussing the requirements of the American market.

Mr. J. O. Bowley has been appointed a Director and General Manager of A.E.C. Ltd. Mr. Bowley joined A.E.C. Ltd. in 1926 and after 24 years in various posts, resigned to take up the position of Works Manager at Guy Motors Ltd. Subsequently, he joined the Ministry of Supply and was appointed the Duty Chief Engineer at the Fighting Vehicles Research and Development Establishment at Chobham, which appointment he held until rejoining A.E.C. Ltd. in 1955 as General Works Manager. **Mr. George D. Robinson,** who has been chief engineer since 1950, has also been appointed to the Board of A.E.C. Ltd. Mr. Robinson joined the company in 1928 as Chief Designer.

RADIO AND ELECTRONIC COMPONENT SHOW

Recognized as one of the most important technical displays of the year in Great Britain, the 14th annual exhibition organized by the Radio and Electronic Component Manufacturers' Federation is to be held at Grosvenor House and Park Lane House, Park Lane, London, W.1, from Monday, April 8th, to Thursday, April 11th, 1957. Formerly known as the Radio Component Show, the title has now been changed to Radio and Electronic Component Show to be more descriptive of its scope, covering as it does components for the radio, television, telecommunications and electronic industries in their widest aspects.

The exhibition has grown from year to year—next year 160 manufacturers are expected to exhibit—and this has necessitated holding it in two sections which, however, are close together and will be organized and operated as a single exhibition. For overseas visitors and other special guests a pre-view is being held from 10 a.m. to 2 p.m. on the first day, April 8th. Admission is by ticket obtainable from the Secretary, R.E.C.M.F., 21 Tothill Street, Westminster, London S.W.1.



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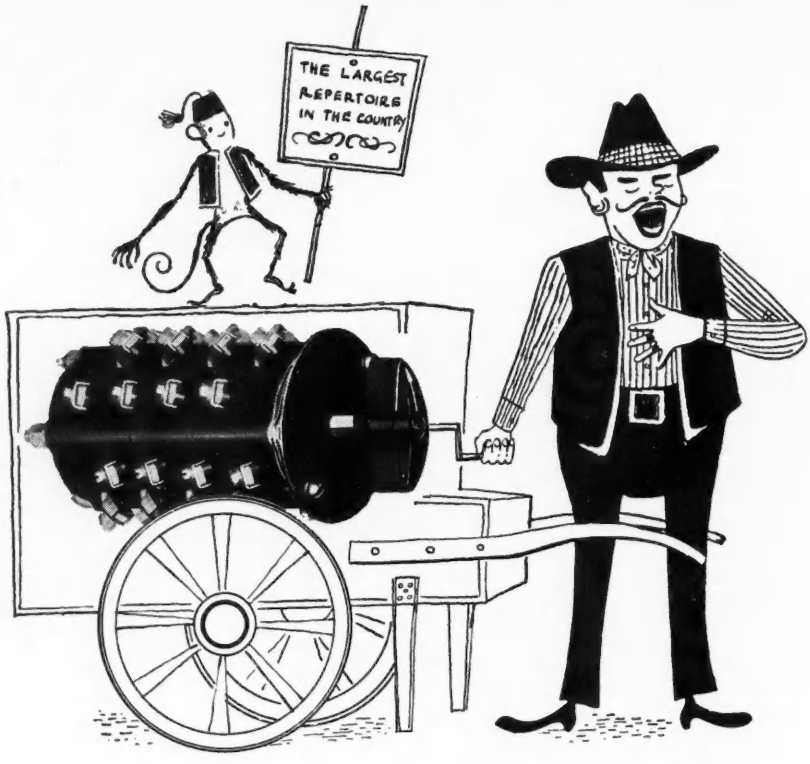

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BUSINESS NOTES

It has been mutually agreed between Index-Verkaufs G.m.b.H. in conjunction with **Index-Werke K.G., Hahn & Tessky of Essligen,** Germany, and **B.S.A. Tools Group,** to terminate their agency agreement as from 1st October, 1956. The agreement provided for the B.S.A. Tools Group to operate as selling agents for German-made Index Machines in this country, and Index-Verkaus G.m.b.H. as selling agents for British-Index Machines in Germany. The termination of these arrangements will in no way affect the continuation of production of British-made Index Machines, and their sale throughout the world. This represents the termination of agreements which have existed between B.S.A. Tools Group and the Index Companies since 1947. The German Index Company's new agents in England will be : **Geo. Kingsbury & Co. Ltd.** (Machine Tools), 54 Victoria Street, London, S.W.1.

British Insulated Callender's Cables Limited announce that the telephone number for their Luton depot is now Luton 7603–4.

Owing to the increase in the general business of Messrs. John Kimbell, a separate Company is now being formed to handle the machine tool section. In the past Messrs. Kimbell have operated in three divisions dealing respectively with Machine Tools, Textile Machinery and Plastics Machinery. The new Company will handle the Machine Tools section from the 1st November and takes the title of **Kimbell Machine Tools Ltd.,** operating from 39 Victoria Street, S.W.1. Kimbell Machine Tools Limited will be agents for the I.W.K. Transfer Presses, Mammut Millers, Schaerer Copying Lathes, May Twist Drill Grinders and Cutter Head Grinders and the Schichau Automatic Flame Cutting Machines, etc.

As from 30th September, 1956, **Salopian Engineers Ltd.** was reconstituted from a manufacturing and sales Company to a marketing Company only. The production resources at Prees have become part of the Contracts Division, and will be known as Contracts Division Factory No. 2. Salopian Engineers Ltd. will market all types of tubular equipment. Mr. A. G. Burgess has been appointed Managing Director of the Marketing Company, retaining his position as Divisional Manager of the Contracts Division.

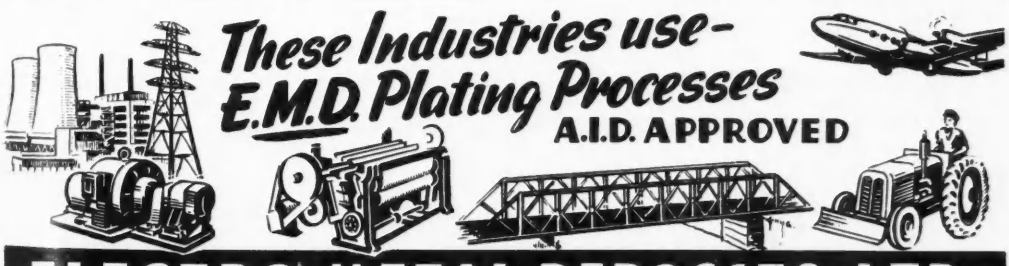
James Holt (Engrs) Ltd., who recently moved into larger premises at Milton Works, Mule Street, Bolton, have already, due to the increased facilities available, added a new press to their well-known range. The Company is now making a 1½/2 ton press. It gives increased daylight and throat depth to meet the range of existing dies available for blanking and piercing tools, usually performed on a hand or fly press.

Rapid Magnetic Machines Limited, of Birmingham, announce that Mr. W. B. Lane, their Managing Director, is making a world trip in a drive for increased exports of the company's specialized separation, extraction and lifting equipment. The journey will be by airline and the itinerary includes India, Ceylon, Singapore, Australia, New Zealand, U.S.A. and Canada. Mr. Lane declares " there is no substitute for on the spot investigation and action in collaboration with the company's agents", and has visited a different country every year since the war.

Mr. R. W. Taylor, C.M.G., B.Sc. (Eng.), M.I.C.E., Engineer-in-Chief to the **Crown Agents for Overseas Governments and Administration,** will pay an official visit to Nigeria during November. He will visit the Federal and three Regional Governments of Nigeria to study and advise on various current engineering projects and relevant matters. Mr. Taylor is expected to arrive back in the United Kingdom on 17th December, 1956.

In order to satisfy a growing demand for industrial control gear **Metropolitan-Vickers Electrical Co. Ltd.** has acquired a new factory at Huyton, near Liverpool, which will eventually employ about 750 people. The site for the new factory covers an area of over 180,000 sq ft and contains a partially completed factory, consisting of a two-storey office block with single-storey manufacturing bays behind. When finished these buildings will occupy about 100,000 sq ft, leaving ample room for additional workshops, offices, canteens, etc. Apart from a few key men from the Company's Trafford Park Works, it is hoped to staff the factory entirely from Huyton and the surrounding area.

W. Mackie & Co. Ltd., 129/137 Lambeth Road, London, S.E.1, announce the appointment of Mr. P. J. Garrini as Sales Manager. Established in 1882, the company was a founder member of The Engineering Industries Association and is well known for its specialized application of design and development knowledge to non-standard requirements. The company have many years of experience in the field of rotating electrical machines and associated control equipment ranging from large Marine Radar Motor Alternators to special, small, vibration free, electrical motors for use in profile flame cutting. Current production includes many types of motors, alternators, rotary converters, rotary transformers and magnetic amplifier type Automatic Voltage Regulators which are purposely designed or adapted in co-operation with the purchasers engineering staff to suit their specific needs. W. Mackie & Co. Ltd., regret that they are unable to prepare a comprehensive catalogue of their range of products since they have produced so many models to diverse specifications. It is also felt that a catalogued description of equipment would detract attention from their main function of manufacturing to the users' specifications.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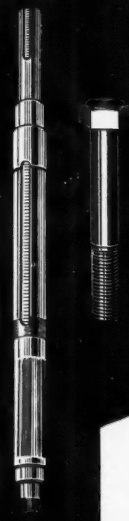

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To mark the occasion of Sir Alfred Herbert's ninetieth birthday and in recognition of his outstanding services to the Industry, the **Machine Tool Trades Association** has instituted a Scholarship to assist engineering students to add to their studies. This Scholarship, the annual value of which will be about £125, is to enable students of Coventry Technical College to widen their knowledge of machine tool design and manufacture and of production methods by visiting engineering works in the British Isles or on the Continent. The award will normally be made in the autumn by Trustees and will include the presentation of a medal. Candidates between the ages of 21 and 30 on 31st July of the year of the award will in general be eligible. The minimum educational standard will be that corresponding to the requirements for Corporate Membership of the Institution of Production Engineers.

The German firm of **Pitzmann & Pfeiffer, Pforzheim,** who are represented in this country by the **Embassy Machine & Tool Company Limited,** 248 Watford Way, Hendon, London, N.W.4, and who have specialized in hydraulic presses for over 100 years, have recently developed a Hydraulic Four Direction Straightening Press for rails, girders and similar sections. The tendency for longer and longer rails has made straightening by means of a single action press extremely difficult owing to the heavy weight which has to be handled, thus making the turning of the rail a very difficult operation. Basically, the press consists of four sets of pressure cylinders and rams carrying the straightening tools. Two cylinders are arranged vertically and two horizontally. Each ram is individually controlled by hand operated pressure valves, there are a total of four arranged in groups of two at a convenient position for the operator who can thus control all movements with both hands.

Birlec Limited, a member of the A.E.I. Group and well known for the manufacture of industrial furnaces and dehumidification equipment, is about to build Britain's largest and most modern electric furnace manufacturing plant. Announcing a ten-year development plan, the company disclosed that a 34-acre site has been purchased at Aldridge near Birmingham. By the end of 1966, Birlec expects to have doubled its present staff.

The new Oil Seal Works of **George Angus & Co. Ltd.,** was officially opened on the 18th October by the Rt. Hon. Major Gwilym Lloyd George. The present buildings, which were completed in eighteen months, provide a total area of 250,000 sq ft and there is room for at least a further 250,000 sq ft of expansion.

The Government of Iraq is setting up an information bureau in London. It is taking offices, for the time being, in the Iraqi Embassy, at 21 Queen's Gate, S.W.7. Mr. Abdul Aziz Al Mudhaffer, O.B.E., a former Director-General of the Iraq Ministry of Foreign Affairs, has been appointed director of the new bureau. " The main object of the new bureau," Mr. Mudhaffer said, " is to strengthen Anglo-Iraqi friendship and understanding. We hope to facilitate commercial contacts between the two countries, to encourage ordinary Britons to visit Iraq, and to make more widely known in Britain the story of Iraq, both in regard to its ancient history and its modern development." There is immense scope for trade co-operation between the two countries, Mr. Mudhaffer added. He pointed out that Iraq is now spending about £100 million a year on all kinds of projects, from dams and power stations to schools and hospitals.

The Hoffman Manufacturing Co. Ltd. have published a new brochure entitled "Bearing Symbols with Hoffman Equivalents" intended to help designers and those engaged on servicing work to easily identify a bearing and to replace it with a Hoffman equivalent.

Further plans have now been revealed showing the method that **Colt Ventilation Ltd.** are employing in the sale of their equipment in the United States. Following an extensive Market Research during 1955 and 1956 it was decided that a subsidiary Company must be formed and Mr. I. J. O'Hea, Managing Director, with Mr. M. J. Reaney, Director and General Manager, who spent a considerable time in the States, decided that the company would be located in Los Angeles.

The address is Colt Ventilation of America Incorporated, P.O. Box 27101, 4652, Hollywood Boulevard, Los Angeles 27. Telephone Normandy 1-0261. Stocks of equipment have already been shipped to the U.S.A. while a National programme of advertising in the press and on the radio and television is now in operation. Mr. H. M. McLean, previously Area Manager for Scotland was made the Manager and has recently reached Los Angeles. Mr. Reaney has been in charge of the initial organization of the company and the arrangements for a series of lectures on ventilation to selected groups of American Architects, Engineers and Industrialists.

The Society of Motor Manufacturers and Traders announce the publication of the 1956 edition of their book *The Motor Industry of Great Britain* which contains facts and figures relating to 1955 in comparison with previous years on the British motor industry and motor industries overseas.

ATOMIC REACTOR LUBRICANT

At Calder Hall Atomic Power Station sixty control mechanisms, which enable the uranium rods to be moved in and out of the reactor, have to be treated and remain lubricated for many years under what were until recently regarded as the most appallingly impossible conditions. Ordinary lubricants are rendered useless by nuclear radiation—sometimes in only a few minutes. Then the atmosphere of dry carbon dioxide in which the mechanisms work also destroys customary lubricants, while atmospheric water vapour is required for graphite lubrication. Metallic contact between working surfaces, even with light loadings and low speeds, can produce seizure under these conditions. The alternative was to replace frequently unlubricated controlling mechanisms as they rapidly became worn which would have been an expensive process seriously interfering with the continuous production of electricity by atomic power.

Exhaustive tests were carried out on all types of solid lubricants in carbon dioxide atmospheres of high pressures and temperatures, and the lubricants based on molybdenum disulphide (MoS_2) manufactured by **Rocol, Ltd.,** were found to be worthy of attention.

With a background of thousands of special cases of the use of lubricants under many difficult conditions, Rocol Ltd. evolved a varnish producing a molybdenum disulphide film, known as "Molytox". This was adopted and the control mechanisms are lubricated by dry treatments with this material. Thus, British research, development and know-how have contributed towards ensuring that the world's first commercial atomic power station will run simply, easily and safely in the future.

Not only does Rocol "Molytox" lubricate, but it protects the control mechanisms from corrosion by carbon dioxide, heat and humidity. For this reason it is also being used for treating replacement equipment, and for the pre-treatment of control equipment, destined for use in other reactors, to be held in storage. For very special conditions, such as in an emergency and for the pre-treatment of surfaces which may have to be exposed to abnormal conditions of moisture and corrosion, a "reactor fluid" based on a silicone varnish containing molybdenum disulphide has been developed and used with success. In principle it is identical with "Molytox", but the presence of a water repellent silicone gives it added protective capacity.

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HIGH SPEED, LIGHT TYPE, CENTRALISED CONTROL RADIALS

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BRITISH STANDARDS

(Copies of British Standards may be obtained from the British Standards Institution, 2 Park Street, London, W.1)

Dimensions of 3-phase electric motors B.S. 2083: 1954 has helped industry by providing for the complete mechanical interchangeability of various makes of squirrel-cage motors. Two important additions in the revised edition, now published as B.S. 2083 : 1956, further strengthen this standard's usefulness. The first is the inclusion of maximum overall external dimensions, which, though still allowing for variations between individual manufacturers, will enable the purchaser to calculate the minimum space needed to accommodate any make of motor. The other main change extends the standard's cover to the dimensions of flange-mounted motors ; the requirements on foot-mounted motors remain substantially the same.

The standard applies to industrial 3-phase 50 c/s motors with continuous maximum ratings in the range 1 to 20 h.p. (at 1,500 r.p.m. synchronous speed) and voltages up to 650 V. With one exception the dimensions specified are similar to those which were given in the 1949 edition of the American NEMA standard MG1 but for a given frame size the horse-power outputs have been increased ; shaft dimensions and tolerances have, therefore, been adjusted to suit British practice. Price 3*s*.

Turnbarrels, tension rods and swaged cable-end connections (UNF threads) for aircraft. B.S. 2SP. 101–104 : 1953. The publication of revised editions of the above British Standards is announced. Items with No. 8–32 UNC and No. 10–32 UNF threads have now been provided for in the standards, thus presenting users with a complete range of aircraft cable-end connections with Unified threads. The standards provide a tensioning device for aircraft control cables, and a variable range of cable-end fittings, as a safeguard against the crossing of controls. Price for complete revised Standard is 5*s*.

Terminology of internal defects in castings as revealed by radiography. B.S. 2737 : 1956. The need for rationalizing the terminology of defects in castings was realized when the Non-destructive Testing Group (formerly the Industrial Radiology Group) of the Institute of Physics initiated the preparation of the present standard. Different workers in the field, such as radiologists, metallurgists, foundrymen and engineers, commonly use various terms for one type of defect and also at times use the same term for more than one defect. There is variation from industry to industry, and even from foundry to foundry. For example, the term " porosity " has been applied to different types of defect according to the metal or alloy concerned, and therefore the use of the term is to be deprecated unless it is adequately qualified, e.g. " microporosity ".

The purpose of this standard is to enable the interpretation of casting radiographs to be understood without ambiguity of terminology, by those interested in the radiographic inspection of castings. To this end the terms have as far as possible been chosen to correlate the definitions with their metallurgical or foundry origin. The aim has been to select those terms which will be applicable to all the metals normally used in castings. The defects listed have been classified into five groups of associated types with sub-divisions. A separate section is included relating to diffraction mottling, which arises from purely crystallographic causes, and should not be regarded as a defect.

The terms and definitions used in the standard are illustrated by radiographs, which have been selected not only to show the salient features of the defects, but also because of their suitability for reproduction by half-tone blocks. These illustrations are intended solely to be complementary to the definitions of the defects, and not as criteria of their severity. Some of the radiographs have been supplemented by macrographs or micrographs to help to appreciate the nature of the defect. Price 12*s*. 6*d*.

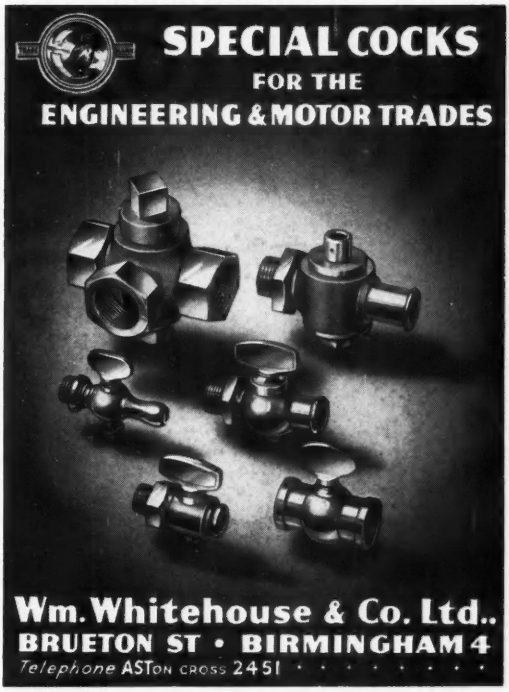
Electrical equipment of machine tools. B.S. 2771 : 1956 deals with control apparatus, motors, wiring and related accessories which are furnished as part of the machine tool and originate at its isolating switch. It specifies the conditions under which the equipment is applied on machine tools ; and its application will ensure the safety of personnel, uninterrupted production and adequate length of service from the electrical equipment. Price 5*s*.

Definitions of heat insulating terms and methods of determining thermal conductivity. B.S. 874 : 1956. Part I of B.S. 874 contains definitions of heat insulating terms and a summarized list of relevant symbols and dimensions of units. The measurement of thermal conductivity and emissivity is described in Part II, including methods used for different types of materials for various temperature ranges. Conversion tables for units in common use are provided in the Appendices.

As in the previous edition, a purpose of Part I of this standard is to provide means of establishing consistency in definitions of terms, particularly in order that there should be as little conflict as possible with analogous terms used in other countries and with the view to rectifying confusion which may exist in the use of such words as conduction, conductance and transmission.

One of the changes made is the adoption of the joule as the fundamental unit of heat in accordance with B.S. 350 : 1940, Amendment No. 4, October, 1953 (P.D.1715), which also defines the corresponding values for the revised steam table British thermal unit and the revised steam table calorie. The effect of this change on heat insulation calculations is negligible.

A complete revision has been made of the methods used for measuring thermal conductivity, thermal conductance and thermal transmittance of heat insulating materials and structures. Since properties of materials, including thermal conductivity, may change during the working life, provision is not made in this standard for general requirements for thermal insulating materials. Price 5*s*.



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SERVICE ACKNOWLEDGEMENT

The machine is now in satisfactory working condition.

~~The machine is not working to our satisfaction.~~

Remarks:- We will take this opportunity to tell you that application of the borer to our multi-cavity mould requirements, has permitted complete revision of method, resulting in greatly increased efficiency and economy.

Additionally we commend the attention and service given by your Company, from the enquiry stage, through to the exchange of this document.

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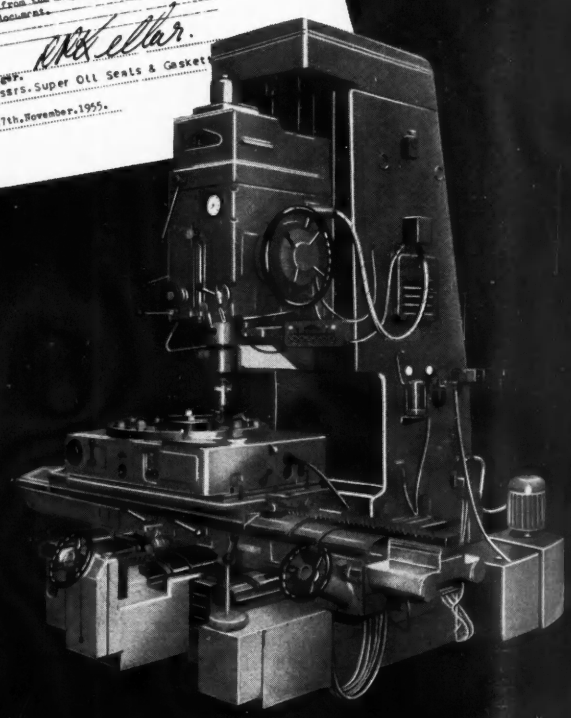

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CONTRACTS

The award of a $92 million contract to an American construction firm—believed to be the biggest "turnkey" contract of its type ever signed in the U.S.A.—has brought The English Electric Company sub-contracts for hydro-electric machinery and associated equipment worth approximately $24 million. The $12 million order recently announced by the Grant County Commissioners covering water turbines formed part of this contract. The main contract is for the construction of a new dam and power house at Priest Rapids on the Columbia River. It has been given by Grant County Public Utility District No. 2 of Ephrate, Washington State, in the Pacific Northwest, to the internationally known construction firm, Merritt-Chapman & Scott Corporation, whose headquarters are in New York. The Merritt-Chapman & Scott bid included English Electric water turbines, generators and transformers and a contract for this equipment, valued at approximately $24 million, has accordingly been awarded to **The English Electric Export and Trading Company Ltd.**

A contract worth £100,000 for the supply of rotary drilling equipment to China has been won by **Victor Products (Wallsend) Ltd.**, of Wallsend-on-Tyne, Northumberland. The equipment is required in connection with the large scale development of the mining industry in China, and the contract is believed to be one of the largest ever placed for rotary drilling equipment. Victor Products have specialized in the production of this equipment for many years.

The Belgian Naval Authorities have just placed an order for £50,000 worth of Engine Protection Equipment with **Teddington Industrial Equipment Ltd.** The equipment is for use with the main propulsion and auxiliary engines in a number of Inshore Minesweepers to be built in Belgium for use by N.A.T.O. forces and is the culmination of orders totalling £125,000 for similar equipment supplied under the N.A.T.O. Defence Programme. Negotiations are also already well advanced with the Italian, French and Swedish Naval Authorities for the supply of yet further Teddington equipment for use in Minesweepers, High Speed Launches, etc.

The British Transport Commission have announced the award of contracts to **British Insulated Callender's Cables Limited** and **British Insulated Callender's Construction Company Limited** for the design, supply and installation of overhead conductor equipment for Britain's first 25kV single-phase a.c. railway electrification schemes. These contracts form part of the extensive modernization programme of British Railways which will restore national supremacy in the field of railway traction. The first two routes to be electrified under this bold programme are between Manchester and Crewe, and between Colchester, Clacton and Walton. The former route involves 220 track miles of main line of the London Midland Region and includes the electrification of the main lines at Crewe Station—a vital junction for many of the routes to be electrified in the future. The latter route consists of fifty track miles of the Eastern Region of British Railways.

Classified Advertisements

The rate for all classified advertisements is 6d. per word; in bold print 9d. per word; minimum order 6s. Box-number advertisements 1s. extra. Instructions, together with remittance, must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

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Apply:—Personnel Department, Davy and United Engineering Company Limited, Darnall Works, Prince of Wales Road, Darnall, Sheffield 9.

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(b) **Mechanical Designers** of magnetic recording equipment at their Hayes laboratories. A number of interesting projects are in hand giving scope for inventive ability to applicants who have knowledge of electrical circuitry or interest in small mechanisms.

Salaries will be commensurate with ability. Superannuation Scheme.

Apply, giving full details to Personnel Department, (DED/11), E.M.I. Ltd., Hayes, Middlesex.

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200 TONS TAYLOR & CHALLEN DOUBLE SIDED DOUBLE CRANK GEARED PRESS No. 1373 FOR SALE. Stroke 8 in. Between side frames 68½ in. Hole through bed 53 in. × 35 in. Motorized for 400/3/50. Weight 36 tons. Photographs and full details from: **F. J. EDWARDS LTD., 359 Euston Road, London,** or **41 Water Street, Birmingham.**

10 ft. x ¾ ins. CRAIG & DONALD PRESS BRAKE FOR SALE. All steel construction. Model 400/10. Motorized with 50 hp motor suitable for 400/3/50. **F. J. EDWARDS LTD., 359 Euston Road, London, N.W.1,** EUSton 4681, and **41 Water St. Birmingham 3.** CENtral 7606.

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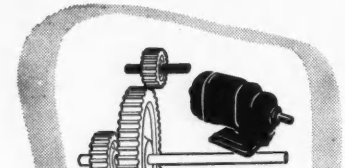

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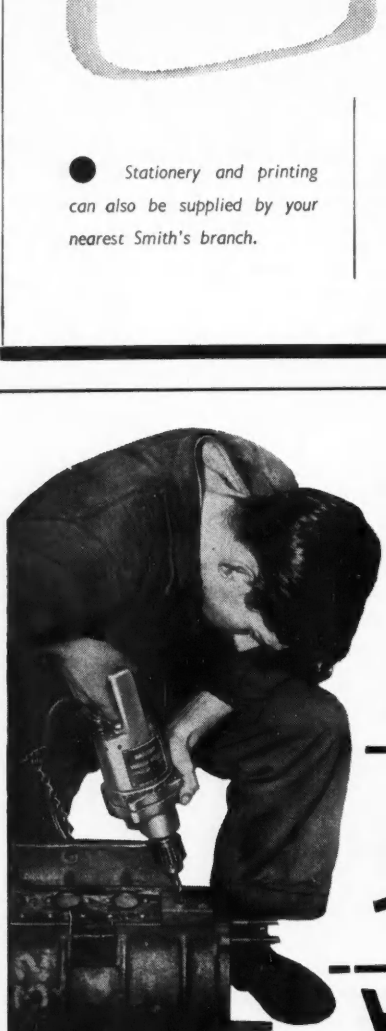

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BOOKS RECEIVED

Analysis of Electric Circuits. By William H. Middendorf. 320 pp., 310 illustrations. Publishers : John Wiley & Sons, Inc., New York, and Chapman & Hall, Limited, 37 Essex Street, London, W.C.2. Price : 48/–.

In order to assist the instructor in the important task of introducing students to the subject of circuit analysis, Professor Middendorf first sets forth six basic physical laws and definitions established by the early experimenters. He then shows the reader that he needs only to learn the meaning of these six laws and to apply them with complex algebra. The author treats only those topics which are most essential to a basic understanding of the subject, and these are presented in detail and accompanied by a variety of numerical examples and problems. Each article and chapter leads naturally and logically to the succeeding chapter.

The emphasis of the book is on developing the ability of the reader to think for himself, so much so that the examples and problems have been specially designed with this end in view. Proofs, rather than mere presentation, are accented. Furthermore, the book has been conveniently arranged into three sections. Of these, the first section provides all that is necessary to meet the problems encountered in the usual undergraduate course, while the remaining sections serve to extend the scope of the work. A feature which is unusual in a book of this kind is the inclusion of a useful chapter on communication circuits.

Drawings and Dimensions. By S. Parker, B.E.M. 320 pp., 242 illustrations. Publishers : Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price : 35/–.

The author of this volume—an acknowledged expert in his field—was one of the first in Great Britain to realize and explain the necessity, from the point of view of economical and increased engineering production, for the establishment of a standard, simple, and logical language for the dimensioning and tolerancing of engineering drawing, capable of being universally understood by designers, manufacturers, and inspectors. Eventually, in 1953, as a result of the joint efforts of the British Services and industry—in which the author played a prominent part—the British Standard " Engineering Drawing Practice, B.S. 308 " was issued.

As the full implementation of B.S.308 necessitates more knowledge than can reasonably be given in a British Standard, this book has been written to explain more fully the principles of geometry on which the dimensioning and tolerancing methods outlined in the Standard are based. Emphasis is also laid on how serious hindrance can be caused to efficient production by wrongly dimensioned drawings.

There can be no doubt that designers, production engineers and inspectors, jig, tool, and gauge designers and makers, and engineering craftsmen and students will find this well-produced and conceived book an invaluable companion to B.S. 308.

Body Engineering (Design and Construction of Motor Vehicle Bodywork). Second Edition, 1956. By Sydney F. Page, M.I.B.C.A.M., M.M.I.A., A.M.I.E.D. 190 pp., 146 illustrations. Publishers: Chapman & Hall, Limited, 37 Essex Street, London, W.C.2. Price: 25/–.

Despite the fact that motor-vehicle bodywork has been an industry for many years, comparatively little instructive material has been available in the form of textbooks. This book admirably complements existing literature and is of undoubted value not only to designers and draughtsmen but also to all others concerned with body engineering.

Divided into eight sections, this second edition, which has been brought up to date by the inclusion of information relating to recent developments, such as the application of rubber wings and the use of reinforced plastics, commences with an introduction dealing with the history of motor-car bodies and with construction trends. Then follow sections on the materials used in bodywork, bodywork designing and drafting, sheet-metal projection, caravans and trailers, bodywork interiors, and practical bodywork construction. A useful constructional supplement, comprising a series of tables and constructions for bodywork, is appended.

Planetary Gearing. By H. W. Hardy, A.M.I.Mech.E. 60 pp., 13 illustrations. Publishers: The Machinery Publishing Co., Ltd., National House, West Street, Brighton 1. Price: 4/6.

This new book, No. 37 in " Machinery's " Yellow-Back Series, indicates a clear method of approach to the subject of the design and efficiency of planetary gearing and, as such, enables readers to solve more readily problems in planetary gearing. The exposition of the subject is based on the equivalent-lever and tabular methods, and the book includes a number of fully worked examples, together with methods of calculating the efficiency of single or multiple units.

Textile Machinery Index. First Edition, 1956. 650 pages. Publishers: John Worrall Ltd., Central Works, Oldham. Price: 42/–.

Compiled, in association with the Textile Machinery and Accessory Manufacturers' Association, by a Company with over 70 years of experience in the field of textile publishing, " Textile Machinery Index " comprehensively details virtually every phase of the activities of the textile engineering and accessories industry. As such, it succeeds admirably in presenting a complete technical catalogue of the subject.

An especially valuable feature of this well-produced volume is the system of indexing employed, providing, as it does, an extremely simple and rapid means of access to any required information, which has been conveniently divided into sections, with thumb-hole subsections. As a further aid to rapid reference, contrasting paper colours have been used for special sections. With its enormous scope and coverage, this book will undoubtedly prove of inestimable value to all those interested in the various sources of supply for the mills and for the textile engineering and ancillary industries.

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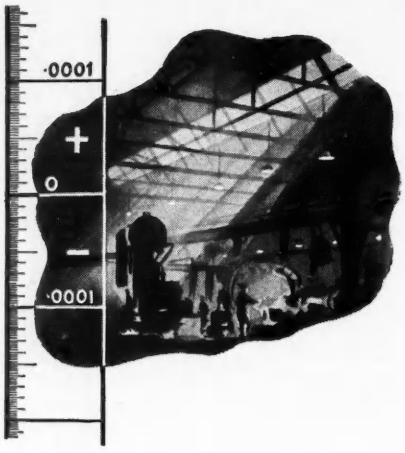

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